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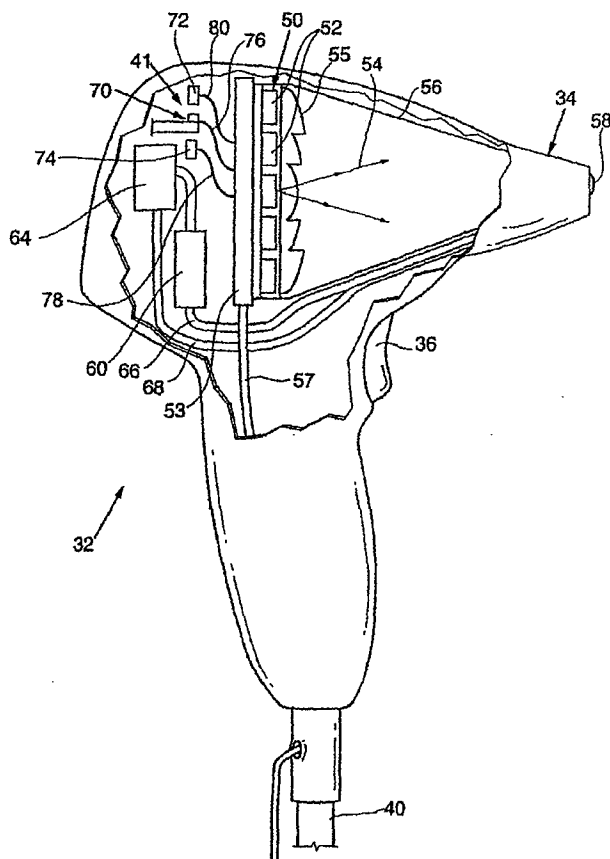
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(54) Title: AUTOMATIC FIRING APPARATUS AND METHODS FOR LASER SKIN TREATMENT OVER LARGE AREAS



(57) Abstract: Laser skin treatment apparatus includes a handpiece for delivering laser-radiation pulses from a laser to an area of skin being treated. The area being is larger than an area treatable in a single firing of the laser. The larger area is treated by treating adjoining sub-areas within the larger area by repeated firings of the laser. The laser is fired automatically depending on the position of the handpiece in the larger area. Several arrangements for determining the position of the handpiece are disclosed. These include optical detection by the handpiece of indicia drawn on the skin being treated; optical, magnetic, or mechanical detection of indicia on a separate guide for the handpiece or on a roller attached to the handpiece; and detection by determining time of travel of signals from a transponder in the handpiece to a fixed reference plane.



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**AUTOMATIC! FIRING! APPARATUS! AND! METHODS! FOR
LASER! SKIN! TREATMENT! OVER! LARGE! AREAS**

5

TECHNICAL! FIELD! OF! THE! INVENTION

The! present! invention! relates! in! general! to
apparatus! for! laser! skin! treatment,! such! as
depilation. The! invention! relates! in! particular! to
an! automatic! repeat! firing! system! for! laser! skin
10 treatment! apparatus! which,! in! a! single! firing,! can
treat! only! a! relatively! small! sub-area! of! an! area! of
skin! to! be! treated.

DISCUSSION! OF! BACKGROUND! ART

In! laser! dermatological! treatment! operations
15 such! as! depilation,! an! area! of! skin! to! be! treated! may
often! be! much! greater! than! the! area! which! can! be
treated! by! a! single! firing! of! laser! apparatus.
Typical! apparatus! for! laser! treatment! includes! a
handpiece! for! delivering! laser! radiation! from! a! laser
20 to! skin! being! treated.! The! laser! may! be! remote! from
the! handpiece! with! the! laser! radiation! being
delivered! to! the! handpiece! via! an! optical! fiber! or
articulated! arm. Alternatively,! the! laser! radiation
may! be! provided! by! a! diode-laser! array! incorporated
25 in! the! handpiece. A! handpiece! is! often! furnished
with! a! cooled! window! which! is! placed! in! contact! with
the! skin,! laser! radiation! being! delivered! to! the! skin
through! the! cooled! window.

Treatment! of! a! large! area! of! skin! is! typically
30 accomplished! by! an! operator! manually! firing! the! laser
apparatus,! with! the! handpiece! located! in! one! position
on! the! area! of! skin! being! treated,! then! moving! the

handpiece! to! another! position! in! the! treatment! area
and! manually! firing! the! laser! apparatus! again.! One
disadvantage! of! this! method! is! that! it! can! be
difficult! to! precisely! and! contiguously! locate
5 treated! sub-areas! of! the! total! area! being! treated
such! that! no! sub-area! is! left! untreated! and! no
overlapping! of! treated! sub-areas! occurs. Another
disadvantage! of! this! method! is! that! time! taken! to
relocate! the! handpiece! from! a! treated! sub-area! to! an
10 adjacent! untreated! sub-area! can! prolong! the! treatment
operation. This,! in! turn,! can! lead! to! an! increased
cost! of! the! operation.! The! apparatus! and! method! of
the! present! invention! is! intended! to! overcome! these
disadvantages.

SUMMARY! OF! THE! INVENTION

The! present! invention! is! directed! to! a! method! of
treating! an! area! of! skin! with! a! laser! by! delivering! a
series! of! laser-radiation! pulses! to! the! skin.! Each
of! the! laser! pulses! treats! a! sub-area! of! the! area! to
20 be! treated.

In! one! aspect! of! the! present! invention,! a! laser
is! provided! which,! on! being! fired,! generates! a! pulse
of! laser-radiation. A! handpiece! is! provided! and
arranged! for! delivering! a! pulse! of! laser-radiation
25 from! the! laser! to! the! skin! being! treated.

While! the! handpiece! is! being! moved! over! the! skin
being! treated,! the! location! of! the! handpiece! in! the
area! of! skin! being! treated! is! electronically
determined,! and! the! laser! is! automatically! fired! when
30 the! electronically! determined! location! corresponds! to
a! sub-area! to! be! treated.

The! terminology! "automatically! fired"! here! means
that! as! the! firing! of! the! laser! is! electronically
triggered! by! the! electronic! position! determination
35 without! operator! intervention! other! than! moving! of

the! handpiece. The! terminology! "laser"! means! a! laser
resonator! including! a! gain! medium! (which! may! be! a
diode-laser! or! array! of! same)! and! those! electrical
and! electronic! circuits! needed! to! power! the! laser! and
5 to! switch! or! modulate! the! laser! to! provide! the! laser-
radiation! pulses.

In! one! embodiment! of! the! present! invention! the
location! determining! step! includes! providing! a
plurality! of! regularly! spaced! indicia! on! or! adjacent
10 the! area! of! skin! being! treated.! At! least! one! sensor
is! provide! on! the! handpiece! and! arranged! to! detect
passage! of! the! handpiece! by! one! or! more! of! the
indicia! as! the! handpiece! is! moved! over! the! skin! being
treated. The! automatic! firing! is! triggered! by! the
15 passage! of! the! handpiece! by! one! or! more! of! the
indicia. The! indicia! may! be! graphic! indicia,
magnetic! indicia,! or! mechanical! indicia.

In! one! example! of! this! preferred! embodiment! of
the! present! invention,! the! indicia! are! graphic
20 (optically! detectable)! indicia. The! sensor! includes
a! light-source! arranged! to! direct! light! onto! the! skin
being! treated! such! that! the! thus! directed! light! is
scattered! by! the! skin! being! treated.! The! sensor
includes! one! or! more! light! detectors! arranged! to
25 detect! the! light! scattered! by! the! skin.! The! graphic
indicia! are! equally-spaced! parallel! lines! drawn! on
the! area! of! skin! being! treated! in! a! medium! which! is
opaque! to! the! wavelength! of! light! emitted! by! the
light-source! and! transparent! to! the! wavelength! of
30 said! pulse! of! laser! radiation.! Passage! of! the
handpiece! by! any! one! of! the! indicia! (crossing! any! one
of! the! lines)! results! in! a! reduction! in! the! scattered
light! detected! by! the! detector.! The! reduction! in
scattered! light! indicating! that! one! of! said! indicia
35 has! been! passed,! i.e.,! a! line! has! been! crossed.

In! another! embodiment! of! the! present! invention
the! location! determining! step! comprises! providing! a
roller! on! the! handpiece,! the! roller! being! arranged! to
contact! the! skin! being! treated! and! rotate! in! response
5 to! the! handpiece! being! moved! over! the! skin! being
treated. The! roller! has! a! plurality! of! regularly
spaced! indicia! thereon. At! least! one! sensor! is
provided! on! the! handpiece.! The! sensor! is! arranged! to
detect! passage! by! the! sensor! of! one! or! more! of! the
10 indicia! as! the! roller! rotates.! The! automatic! firing
is! triggered! by! the! passage! by! the! sensor! of! one! or
more! of! the! indicia.

The! indicia! on! the! roller! may! be! radially
extending! lines! on! a! side! of! the! roller! or
15 longitudinally! extending! lines! on! a! cylindrical
surface! of! the! roller.! The! indicia! in! either! case
may! be! graphic! (optically! detectable)! indicia! or
magnetic! (magnetically! detectable)! indicia. In! one
variation! of! this! embodiment,! indicia! can! be! omitted
20 from! the! roller! and! the! roller! axially! connected! to! a
shaft! encoder,! the! shaft! encoder! providing! signals
used! for! the! electronic! position! determination.

In! yet! another! embodiment! of! the! present
invention,! the! location! determining! step! comprises
25 providing! a! screen! adjacent! the! skin! being! treated.
A! transponder! is! provided! on! the! handpiece.! The
transponder! is! arranged! to! emit! a! regular! train! of
signal-pulses! toward! the! screen! such! that! the! signal-
pulses! are! incident! thereon! and! a! return-pulse
30 corresponding! to! each! of! the! incident! signal-pulses
returns! to! the! handpiece. A! receiver! is! provided! on
the! handpiece! for! receiving! the! return! pulses.! An
elapsed! time! between! emitting! a! signal-pulse! and
receiving! a! corresponding! return-pulse! is! determined.
35 The! elapsed! time! is! representative! of! the! location! of
the! handpiece.

The signal-pulses are preferably ultrasonic pulses. However, the use of other forms of signal pulses is possible, for example optical pulses or radar pulses.

5 In still another embodiment of the present invention the location determining step also includes providing a transponder on the handpiece. The transponder is arranged to emit a regular train of signal-pulses each thereof in diverging beam. At
10 least two spaced-apart receivers are provided. The receivers are located in a position remote from the handpiece, within the divergence of the beam, for receiving said signal pulses. Based on the spacing of the receivers and an arrival time of the signal
15 pulses at the receivers, the location of the handpiece is determined in at least length and width dimensions of the area of skin to be treated. For an area of skin to be treated which is contoured, three spaced-apart receivers may be provided, and the
20 location of said handpiece in the area of skin to be treated determined in length width and height dimensions.

In another aspect of the present invention, the handpiece may be equipped with a skin contact-sensor
25 for determining whether or not the handpiece is in contact with skin being treated. This is useful in laser skin treatments wherein laser radiation is delivered to the skin via a lens or transparent body (applicator) incorporated in the handpiece and in
30 contact with the skin for promoting efficient coupling of laser radiation into dermal layers.

In one preferred embodiment of skin-contact sensing in accordance with the present invention, a
light-source is provided having an exit-aperture
35 thereof on the handpiece. The exit-aperture is configured to be in contact with the skin being

treated! when! the! applicator! is! in! contact! with! the
skin! being! treated.! Light! from! said! light-source! is
delivered! via! said! exit-aperture! thereof! such! that,
when! the! applicator! is! in! contact! with! the! skin,
S light! delivered! the! said! exit-aperture! is! transported
laterally! through! the! skin! via! volume! scattering! of
the! light. A! detector! is! provided! having! a
receiving-aperture! on! the! handpiece! proximate! the
light-source! exit-aperture. The! output! of! the
10 detector! is! monitored.! The! monitored! detector-output
is! interpreted! as! an! indication! that! the! applicator
of! the! handpiece! has! made! or! lost! contact! with! the
skin! being! treated.

The! above-described! contact! skin! contacting
15 method **is** not! limited! to! a! handpiece! delivering
laser-radiation! for! skin! treatment! but! is! applicable
to! handpiece! delivering! electromagnetic! radiation
(for! skin! treatment)! from! an! incoherent! source! such
as! a! flashlamp.! An! above-described! sensor! for
20 detecting! graphic! indicia! may! be! configured! to
additionally! function! as! a! skin! sensor! for
implementing! the! above-described! skin-contact! sensing
method.

Preferred! embodiments! of! the! present! invention
25 are! described! in! detail! hereinbelow! with! reference! to
a! laser! hair! removal! apparatus! using! an! array! of
diode-lasers. Automatic! firing! arrangements! in
accordance! with! the! present! invention! are! neither
limited! to! apparatus! including! diode-lasers,! nor
30 limited! to! hair! removal! apparatus.! Those! skilled! in
the! art! will! recognize! that! automatic! firing
principles! of! the! present! invention! are! applicable! to
laser! apparatus! including! other! laser! types,! for
example,! solid-state! lasers,! to! apparatus! wherein
35 treatment! light! is! provided! by! an! incoherent! source
of! electromagnetic! radiation! such! as! a! flashlamp,! and

to! other! laser! skin! treatments,! for! example,
treatment! of! vascular! lesions! such! as! "port! wine"
stains.

BRIEF! DESCRIPTION! OF! THE! DRAWINGS

5 The! accompanying! drawings,! which! are.
incorporated! in! and! constitute! a! part! of! the
specification,! schematically! illustrate! a! preferred
embodiment! of! the! present! invention,! and! together
with! the! general! description! given! above! and! the
10 detailed! description! of! the! preferred! embodiment
given! below,! serve! to! explain! the! principles! of! the
invention.

FIG.! 1! is! a! perspective! view! schematically
illustrating! a! first! preferred! embodiment! of! laser
15 treatment! apparatus! in! accordance! with! the! present
invention! having! a! first! handpiece! including! a
chilled! tip! and! having! a! position! sensor! located
therein,! the! handpiece! being! movably! connected! to! a
control! console! for! controlling! operating! parameters
20 of! the! apparatus.

FIG.! 2! is! a! rear! elevation! view! of! the! handpiece
of! FIG.! 1! schematically! illustrating! the! handpiece
being! moved! in! a! direction! orthogonal! to! a! regular
grid! of! parallel! lines! drawn! on! an! area! of! skin! being
25 treated.

FIG.! 3! is! a! partially-cutaway! side! elevation
view! of! the! handpiece! of! FIG.! 1! schematically
illustrating! a! light-source! and! photodetectors! of! the
position! sensor! for! respectively! sending! light! to! and
30 receiving! light! from! optical! apertures! in! the! tip! of
the! handpiece.

FIG.!4 is! a! partial! front! elevation! view! of! the handpiece! of **FIG.!1** schematically! illustrating details! of! the! chilled! tip! of! the! handpiece! and optical! apertures! of! the! sensor! therein.

5 **FIG.!5** is! a! partial! cross-section! view! of! the handpiece! of **FIG.!1** seen! generally! in! the direction 5-5 of! **FIG.! 4**! and! schematically illustrating! further! details! of! the! position! sensor in! the! handpiece.

10 **FIG.!6** is! a! rear! elevation! view! schematically illustrating! a! second! handpiece! in! accordance! with the! present! invention! arranged! for! automatic! firing in! both! longitudinal! and! lateral! directions! of! motion thereof.

15 **FIG.! 7**! is! a! partial! front! elevation! view! of! the handpiece! of **FIG.!6** schematically! illustrating details! of! the! chilled! tip! of! the! handpiece! and optical! apertures! of! four! position! sensors! therein.

20 **FIG.!8** is! a! partial! rear! elevation! view schematically! illustrating! a! third! handpiece! in accordance! with! the! present! invention! arranged! for automatic! firing! by! sensing! crossings! of! lines! on! a ruled! guide-strip! placed,! rulings! uppermost,! in contact! with! skin! being! treated.

25 **FIG.! 9**! is! a! front! elevation! view! of! the handpiece! of! **FIG.! 8**! schematically! illustrating details! of! position! sensors! for! detecting! the! line-crossings.

30 **FIG.!10** is! a! partial! side! elevation! view! of! the handpiece! of **FIG.!8**, schematically! illustrating

further! details! of! one! of! the! position! sensors! for
detecting! the! line-crossings.

5 FIG.! 11! is! a! partial! plan! view! of! the! handpiece
of **FIG.!8** seen! in! the! direction! it-il! of **FIG.!9** and
schematically! illustrating! further! details! of! the
position! sensors! for! detecting! the! line-crossings! and
further! details! of! the! ruled! guide-strip! of **FIG.!8**.

10 **FIG. 12** is! a! partial! side! elevation! view
schematically! illustrating! a! fourth! handpiece! in
accordance! with! the! present! invention! arranged! for
automatic! firing! by! sensing! crossings! of! lines! on! a
ruled! guide-strip! placed! on! edge,! rulings! facing
sideways,! in! contact! with! skin! being! treated.

15 **FIG.! 13** is! a! front! elevation! view! schematically
illustrating! further! details! of! the! handpiece! of
FIG. 12 including! a! side-looking! position! sensor! for
sensing! the! line-crossings.

20 **FIGS.!14** and! 15! are! partial! side! elevation! views
schematically! illustrating! opposite! sides! of! a! fifth
handpiece! in! accordance! with! the! present! invention
arranged! for! automatic! firing! by! sensing! crossings! of
radial! lines! on! wheel! attached! thereto,! the! wheel
arranged! to! contact! skin! being! treated.

25 **FIGS.!15A** and! 15B are,! respectively,! side! and
front! elevation! views! schematically! illustrating
details! of! a! skin-contact! sensor! head! for! the
handpiece! of **FIGS. 14** and! 15.

30 **FIG. 15C** is! a! front! elevation! view! schematically
illustrating! details! of! an! alternative! skin-contact
sensor! head! for! the! handpiece! of **FIGS. 14** and! 15.

FIG. 15D is a graph schematically illustrating detector output as a function of distance from various surfaces of a skin-contact sensor head in accordance with the arrangement of FIG. 15C.

5 FIG. 16 is a plan view from above schematically illustrating further details of the handpiece of FIGS. 14 and 15.

10 FIG. 17 is a partial side elevation view schematically illustrating opposite sides of a sixth handpiece in accordance with the present invention having a wheel attached thereto and connected to a shaft encoder, the wheel arranged to contact skin being treated and the handpiece arranged for automatic firing responsive to signals provided by the shaft encoder.

15 FIG. 18 is a plan view of the handpiece of FIG. 17 seen generally in the direction 18-18 of FIG. 17 and schematically illustrating further details of the wheel and a shaft-encoder and bearing housing on the tip of the handpiece.

20 FIG. 19 is a side elevation view schematically illustrating a ninth handpiece in accordance with the present invention, having a detachable housing including a roller cooperative with a position sensor.

25 FIG. 20 is a perspective view schematically illustrating the detachable housing and roller of FIG. 19.

FIG. 20A is a perspective view schematically illustrating an alternative form of roller for the handpiece of **FIG. 19**.

5 **FIG. 21** is a plan view from below schematically illustrating the handpiece of **FIG. 19** without the detachable housing and showing a vertically-oriented position sensor head for sensing rotation of the roller of **FIG. 20**.

10 **FIG. 22** is a perspective view schematically illustrating a seventh handpiece in accordance with present invention, including a transponder for sending a signal to a screen located proximate a patient being treated, and a receiver for receiving an echo of the signal from the screen for determining
15 the position of the handpiece in one dimension relative to the patient.

FIG. 23 is a perspective view schematically illustrating an eighth handpiece in accordance with present invention, including a transponder for
20 sending a signal to three direction sensitive detectors proximate a patient being treated, signals from the detectors being used for determining the position of the handpiece in at least two dimensions relative to the patient.

25 **DETAILED DESCRIPTION OF THE INVENTION**

Turning now to the drawings, wherein like features are designated by like reference numerals, **FIG. 1** depicts a first preferred embodiment of laser skin treatment apparatus 30 in accordance with the
30 present invention. Apparatus 30 includes a handpiece 32 including a diode-laser array (not shown in **FIG. 1**) for providing laser radiation for treatment. The diode-laser array is alternatively referred to

hereinafter! simply! as! the! laser.! The! diode-laser
array! emits! at! a! wavelength! between! about! 790! and! 830
nanometers! (nm). This! wavelength! range! should! not! be
construed,! however,! as! limiting! the! present
invention.

In! a! tip ³⁴ of! handpiece! 32! are! located! optical
apertures! of! a! position! sensor! incorporated! in! the
handpiece. The! apertures! and! other! components! of! the
position! sensor! are! not! shown! in! FIG.! 1! but! are
described! in! detail! further! hereinbelow. The
handpiece! is! activated! by! a! trigger ³⁶.

Apparatus ³⁰ includes! a! control! console! ³⁸.
Control! console ³⁸ includes,! inter! alia,! power-
supplies,! a! water-supply! and! control! electronics! for
components! of! handpiece ³². The! control! electronics
and! power! and! water! supplies! are! connected! to
handpiece ³² via! an! umbilical! sheath ⁴⁰. When! not! in
use,! handpiece ³² may! be! "parked"! in! a! receptacle ⁴²
in! control! console! ³⁸.! The! operating! sequence! and
treatment! parameters! for! the! apparatus! are! controlled
from! a! touch-screen! display ⁴³.

Referring! now! to! FIG. ², in! one! preferred
method! of! operating! apparatus! ³⁰,! a! grid ⁴⁴ of
equally-spaced! parallel! lines ⁴⁶ **is** drawn! on! skin! ⁴⁸
being! treated. The! grid! preferably! covers! the! entire
area! of! skin! on! which! treatment! is! desired.! Lines! ⁴⁶
are! preferably! spaced! apart! by! a! distance! equal! to! a
linear! dimension! of! the! area! treatable! in! a! single
firing! of! the! laser! or! a! sub-multiple! of! that
dimension. Preferably,! the! area! treatable! in! a
single! laser! firing! is! made! square,! or! at! least
rectangular,! in! which! case! the! spacing! of! lines! ⁴⁶ is
made! equal! to! the! width! or! length! of! the! area! or! some
sub-multiple! thereof. Handpiece! ³² is! moved! in! a
direction! orthogonal! to! lines! ⁴⁶ as! indicated! by

arrows! A,! with! tip! 34! of! the! handpiece! in! contact
with! skin! 48.

5 When! the! handpiece! is! initially! applied! to! the
skin,! the! output! of! detectors! 72! and! 74! (FIG.! 3)! is
stored! by! the! control! electronics! of! console! 38! to
form! a! baseline! reading. This! baseline! reading! will
vary! depending! on! the! skin! reflectivity! at! the
illuminating! wavelength! and! will! be! lower! for! darker
skin! types. The! detection! of! lines! on! the! skin! is
10 based! on! a! drop! in! detector! output! below! a
predetermined! fixed! percentage! of! this! baseline
reading. As! handpiece! 32! is! moved! over! skin! 48! the
position! sensor! of! the! detectors! and! control
electronics! detect! the! crossing! of! a! line! 46! and
15 firing! of! the! laser! is! triggered.

When! apparatus! 30! is! in! the! automatic! firing
mode,! depressing! trigger! 36! on! handpiece! 32! acts! to
enable! automatic! firing! of! the! laser.! The! laser! will
not! fire,! regardless! of! detected! line! crossings,
20 unless! trigger! 36! is! also! depressed.

After! reaching! an! extreme! one! of! lines! 46,
handpiece! 32! is! moved! laterally! by! the! width! of! the
area! treatable! in! the! single! laser! firing,! and
handpiece! 32! is! again! moved! in! the! direction
25 indicated! by! arrows! A.! The! foregoing! sequence! is
repeated! until! the! desired! area! is! treated.
Movements! of! handpiece! 32! in! the! direction! indicated
by! arrows! A! may! be! all! made **in** the! same! direction,! or
alternating! between! forward! and! reverse! directions.

30 Referring! next! to! FIG.! 3,! FIG.! 4! and! FIG.! 5,
further! details! of! handpiece! 32! and,! in! particular,
of! the! position! sensor! therein! (designated! by
numeral! 41! in! FIG.! 3) ,! are! described.! As! noted
above,! handpiece! 32! includes! a! diode-laser! array.! In
35 a! preferred! example,! a! diode-laser! array! 50! includes
a! total! of! ten! diode-laser-bar! stacks! 52! arranged

into rows of five. Each diode-laser-bar stack has a total of nineteen individual edge-emitting diode-lasers. The diode-lasers emit light at a wavelength between about 790 and 830 nanometers (nm). Diode-laser array 50 is assembled on a water-cooled backing-plate 53. Water is supplied to backing-plate 53 from control console 38, via a conduit 57 extending through umbilical sheath 40. Arranged in this way, diode-laser array 50 can deliver up to 1600 Watts (W) of laser-radiation.

Laser-radiation 54 from diode-laser array 50 is converged in the fast axis of the diode-laser bars by cylindrical microlenses (not shown) associated with stacks diode-laser-bar stacks 52, and converged in the slow axis of the diode-laser bars by a Fresnel lens 55. The laser radiation is then guided by a tapered light-guide 56 toward a lens 58, preferably of sapphire, in tip 34 of handpiece 32. Lens 58 most preferably has a square aperture to facilitate "tiling" together of sub-areas treated by single firings of the laser as described above with reference to FIG. 2.

Lens 58 has a contact surface 59 and is cooled by a cooling-fluid, preferably a mixture of water and ethylene glycol, chilled by a thermo-electric cooler (TEC) 60 (see FIG. 3). The cooling-fluid is circulated through a copper microchannel-cooling jacket 62 (see FIG. 5) in thermal contact with lens 58. Circulation of the cooling-fluid is effected by a pump 64 via delivery and return conduits 66 and 68 respectively (see FIG. 3).

Sensor 41 includes a light-source 70 (see FIG. 3), preferably a semiconductor light-source, such as a light-emitting diode (LED) or the like, and two photodetectors 72 and 74, such as photodiodes. These photodetectors are connected via electrical

connections! (not! shown)! through! umbilical! sheath! 40
to! control! electronics! in! console! 38.

Light! from! light-source! 70! is! guided! by! an
optical! fiber! 76! to! tip! 34! of! handpiece! 32! (see
5 FIGS.! 3,! 4! and! 5) .! Light! exiting! optical! fiber! 76
incident! on! skin! 48! is! scattered! through! upper! layers
of! the! skin.! A! portion! of! the! scattered! light! enters
optical! fibers! 78! and! 80! on! opposite! sides! of! optical
fiber! 76. The! end! faces! of! optical! fibers! 76,! 78,
10 and! 80! can! be! considered! as! apertures! of! the! position
sensor! 41! of! handpiece! 32.! Preferably! these! end
faces! are! equally! spaced! in! a! straight! line! as! shown
in! FIG.! 4.! Optical! fibers! 76,! 78,! and! 80! can! be
considered! as! having! proximal! ends! thereof! adjacent
15 light-source! 70! and! detectors! 72! and! 74! respectively,
and! distal! ends! thereof! in! tip! 34.

It! is! also! most! preferable! that! the! optical-
fibers! are! arranged! at! an! angle! to! each! other! in
tip! 34! of! handpiece! 32.! The! angle! converges! towards
20 the! distal! ends! of! the! fibers.! The! angle! is! selected
to! minimize! the! possibility! of! light! from! optical
fiber! 76! entering! optical! fibers! 78! or! 80! by! specular
reflection! from! any! surface.! One! arrangement! found
to! be! optically! effective! and! mechanically! convenient
25 is! that! the! fibers! 78,! 76! and! 80! have! a! diameter
between! about! 0.5! and! 1.5! millimeters! (mm)! and! are
set! the! angles,! in! order! 0! degrees,! 15! degrees,! and
30! degrees! from! the! vertical! (perpendicular! to
skin! 48). The! distal! ends! of! the! fibers! are
30 preferably! as! close! to! each! other! as! is! consistent
with! securely! retaining! them! in! the! sensor! head.! One
reason! for! this! is! discussed! further! hereinbelow.

It! is! important! that! lines! 46! are! drawn! with! a
medium! (ink,! paint! or! the! like)! which! is! transparent
35 to! laser-radiation! 54! from! diode-laser! array! 50,! but
absorbent! for! light! from! light-source! 70. Light! from

light-source 70 must also be able to penetrate skin 48. By way of example, it has been found that for laser-radiation having a wavelength between about 790 and 830 nm, and a light-source 70 in a form of an LED emitting at a wavelength of about 660 nm, an ink containing the dye "Basic Blue 1" (CAS number 3251-06-0) is effective as a medium for lines 46.

Continuing now with particular reference to FIGS. 2 and 5, when end faces of optical fibers 76, 78 and 80 in tip 34 of handpiece 32 are all in contact with skin 48 in a region thereof between lines 46 (or outside grid 44 altogether), both optical fibers 78 and 80 will receive scattered light from optical fiber 76. The light so received will be transmitted to detectors 72 and 74. Control electronics connected to the detectors will record what may be described as a bright condition of the detectors.

As handpiece 32 is moved in the direction indicated by arrows A, either optical fiber 78 or optical fiber 80 will pass over a line 46 depending on the direction of movement (forward or reverse) of handpiece 32. If the width of lines 46 is equal to or greater than the diameter of the optical fibers, the optical fiber instantly over the line 46, and the detector associated therewith, will receive less scattered light because of the absorption of the line-marking medium. In this case, the control electronics will record a dark condition for that detector. Providing two detectors and associated optical fibers, arranged as shown and discussed provides the control electronics with a means of determining the direction of travel of handpiece as discussed below.

The control electronics are preferably programmed to record a "line-crossing" only after

both detectors 74 and 76 have registered a dark condition, in sequence. The sequence in which the dark conditions occur determines the direction of travel. The recorded line-crossing is used by the control electronics to trigger a firing of the laser for treatment. The number of line-crossings recorded can be used to establish a position of tip 34 of handpiece with respect to a starting (datum) point or line.

Another advantage of providing the above-discussed two detectors and fibers is in providing a means for determining whether or not tip 34 of handpiece 32 is in contact with skin 48. If tip 43 loses contact with skin 48, detectors 72 and 74 will simultaneously register a dark condition. Control electronics can be programmed to use such a recorded simultaneous dark condition to prevent firing of the laser either automatically or manually, thereby preventing, for example, firing the laser in an attitude where it may be therapeutically ineffective.

The time interval between line-crossings can be used to determine the speed of travel of tip 34 of handpiece 32 over skin 48. One reason for requiring knowledge of the speed of travel is to prevent handpiece 32 from being moved so quickly that, at the maximum practical firing rate of diode-laser array 52, (the laser) sequentially treated sub-areas of skin 48 can not be contiguous. By way of example, in above-described apparatus 30, the maximum firing rate is between about four and eight Hertz (Hz). Another reason is that too rapid a motion can reduce the effectiveness of chilled lens 58 in cooling skin to be treated.

To optimally prevent such occurrences, it is desirable to know the speed of travel of the handpiece before it has moved completely out of a

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last-treated sub-area of skin 48, and preferably also before the laser is first fired. This can be achieved by spacing lines 46 at some sub-multiple of the width (or length) of a treated sub-area, for example at one-half or one-third that width. Correspondingly, respectively two or three sequential line-crossings will need to be recorded by the control electronics of console 38 in order to trigger a laser firing, while consecutive recorded sequential line-crossings are used to determine the speed of travel of handpiece 32.

From the speed of travel determination, it is possible to provide a simple audible or visual warning of excess speed of travel and even to prevent firing of the laser if a predetermined speed threshold is exceeded. Referring again to FIG. 2, a simple visual display may take the form of three different colored LEDs 82, 84, and 86, located on the back of handpiece 32, these diodes being activated, for example, according to whether the rate of travel is respectively slower than optimal, optimal, or faster than optimal. Those skilled in the art may devise other speed display forms without departing from the spirit and scope of the present invention such as an (apparently) moving bar type or "thermometer" type display of the type often used for sound level indication in electronic sound recording apparatus.

Reasons for preventing a laser firing, be they related to speed of travel or lack of contact, and the position at which firing was prevented can be displayed on display 43 of console 38. This provides that an operator can correct the reasons for prevention of firing and resume automatic firing at the point of termination, or treat individual

untreated sub-areas, one by one, by manually firing the laser.

It is pointed out here that instead of lines drawn in a medium which is darker than the skin as discussed above, it is also possible to employ an
5 medium (ink) containing a fluorescent agent such as fluorescein (resorcinolphthalein, $C_{20}H_{12}O_5$). When excited by light, for instance from a light-source (LED) 70, having a wavelength centered near 494 nm, fluorescein emits light centered at 520 nm. A
10 detector with a matched filter, for example an interference filter having a passband full width at half maximum transmission (FWHM) of 10 nm, at a peak transmission wavelength of 520 nm, can selectively
15 detect this fluorescent emission. Here, since light emission is being detected rather than light absorption, line crossings can be detected equally effectively on skin of any natural color.

It should be noted, here, that in this
20 specification, it is contemplated, unless otherwise stated, that any computation or signal evaluation required for position determination, laser firing decisions and the like is accomplished by one or more electronic processors in control circuitry of
25 console 38. Communication for this purpose with devices incorporated in handpiece 32 and any below described variations thereof is accomplished via umbilical sheath 40 as exemplified above. Any remote displays or sensor devices are assumed to be
30 connected directly to control electronics of console 138. It is emphasized, here, that this assumption is made at least for convenience of description and should not be considered limiting. Those skilled in the art will recognize that
35 processing devices could be located remote from console 38, proximate deviceb which electronic

control! is! required,! for! example,! in! a! handpiece! 32,
or! in! a! computer! such! as! a! personal! computer! (PC) .
Should! such! remote! processing! devices! be! used,! the
manner! of! interconnection! of! the! processing! devices
5 will! be! evident! to! those! skilled! in! the! art! from! the
functional! descriptions! of! embodiments! presented
herein.

Continuing! now! with! a! description! of! other
preferred! embodiments! of! the! present! invention,! a
10 preferred! apparatus! and! method! of! the! present
invention! is! described! above! in! terms! of! automatic
firing! by! detecting! crossings! of! lines! in! a! parallel
grid! of! lines! drawn! on! skin! to! be! treated! with! manual
lateral! shifting! of! handpiece 32 between! linear
15 automatic! firing! sequences.! In! another! preferred
method! and! apparatus! in! accordance! with! the! present
invention,! automatic! firing! is! provided! for! both
longitudinal! and! lateral! movement! of! handpiece 32. A
brief! description! of! this! method! and! apparatus! is! set
20 forth! below! with! reference! to **FIG.16** and **FIG. 7**

Referring! first! to **FIG.16**, a! grid 44X is! drawn
on! skin 48 being! treated! using! a! medium! of! the! types
discussed! above. Grid **44X** comprises! above-discussed
equally-spaced! parallel! lines 46 and,! additionally,
25 another! set! of! equally-spaced! parallel! lines 46X
orthogonal! to! lines **46**. Lines 46 and **46X** are
preferably! spaced! apart! by! a! distance! equal! to
respectively! the! length! and! width! of! the! area
treatable! in! a! single! firing! of! the! laser! or! a! sub-
30 multiple! of! that! dimension.! If! the! area! treatable! in
a! single! laser! firing! is! made! square,! of! course,! the
spacing! of! lines 46 and 46X is! equal. Longitudinal
and! lateral! motion! is! designated! in **FIG. 6** by! arrows
A and! B! respectively.

35 Referring! now! to **FIG.17**, a! handpiece 32X for
practicing! the! method! of **FIG.16** includes! at! least! one

additional! sensor! (not! shown),! similar! to! above-
described! sensor! 41! but! arranged! to! detect! lateral
line-crossings. In! such! a! lateral! line-crossing
sensor,! apertures! of! the! sensor! would! be! aligned
5 orthogonal! to! those! of! above! described! sensor! 41.
This! is! illustrated! in! FIG.! 7! by! apertures! (optical
fiber! ends) **78X,!76X,** 80X. Preferably,! there! are! two
(a! pair! of)! sensors! for! each! direction! as! illustrated
in! FIG. 7 by! the! additional! sensor! apertures.

10 Apertures! for! each! pair! of! sensors! are! parallel! to
each! other! and! spaced! apart,! preferably! by! at! least! a
width! of! a! line! 46! or! 46X.! This! arrangement! avoids
problems! that! would! be! created! by! having! only! one! set
of! sensors! for! a! particular! direction! of! travel
15 aligned! over! a! line! in! the! direction! intended! for! the
sensor! of! the! opposite! direction.

From! the! above! discussion,! those! skilled! in! the
art! will! be! able! to! devise! electronic! processing
logic! for! interpreting! information! from! such! a! set! of
20 sensors! without! further! explanation. One! such
processing! method,! for! example! may! include,
displaying! each! therapeutically-effective,! automatic
firing! of! the! laser! as! a! square! on! display! 43! of
console! 38,! the! position! of! the! square! corresponding
25 to! its! position! in! grid! 44X! of! FIG.! 6.! This! would
provide! an! instant! visual! indication! of! the! existence
and! position! of! any! spots! which! had! not! been
effectively! treated.

Referring! now! to! FIGS.! 8-il,! in! still! another
30 method! of! operating! apparatus! 30,! a! ruled! strip! 90! is
placed,! with! equally-spaced! rulings! 92! thereof
uppermost,! on! skin! 48! to! be! treated! (see! FIG.! 8) .
Rulings! 92! are! preferably! spaced! apart! by! a! distance
equal! to! a! linear! dimension! of! the! area! treatable! in
35 a! single! firing! of! the! laser! or! a! sub-multiple! of
that! dimension,! for! reasons! discussed! above! with

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reference to handpiece 32 of FIG. 2. Rulings 92 may also be arbitrarily spaced by some distance relatively small by comparison with the linear dimension of the area treatable in a single pulse, for example as small as the width of a ruling. This allows detection of many indicia crossings which can enable calculation of increasing or decreasing speed of movement of the handpiece.

A handpiece 32Y, with lens 58 thereof in contact with skin 38, is maintained in contact with strip 90 (see FIG. 11) and moved in a direction indicated by arrows A (see FIG. 8). Tip 34Y of handpiece 32 has its width reduced at its contact end to form steps 94 on each side thereof. Steps 94 preferably have a height just sufficient to allow horizontal surfaces 96 thereof to make contact with strip 90 when tip 34Y is in contact with skin 48 (see FIG. 11).

Handpiece 32Y includes at least one position sensor 41 (light-source and detectors thereof not shown in FIGS. 8-11) including an optical fiber 76 delivering light from the sensor's light-source and optical fibers 78 and 80 for transmitting light to the sensor's detectors. The optical fibers are threaded through handpiece 32Y and are held by a contact block 98 in the above-described alignment and angular relationship of sensor 41 of handpiece 32. Contact block 98 is attached to an extended portion 35 of handpiece 32Y. Extended portion 35 has a width equal to the width of tip 34Y across steps 94. Ends of optical fibers 76, 78 and 80 are held flush with base 102 of block 100 which is flush with horizontal surface 96 of step 94.

Strip 90 is preferably made from a translucent (bulk scattering) material, for example, a fluorocarbon polymer. Rulings 92 are made opaque to

light! from! the! light-source! of! sensor! 41.! It! is! also
possible! to! use! lines! or! rulings! drawn! on! any! diffuse
reflector,! for! example,! dark! lines! drawn! on! white
(bright)! paper! or! white,! (bright)! diffusely-
5 reflective! lines! drawn! on! a! black! (dark)! surface,
i.e.,! a! surface! which! absorbs! light! at! the! wavelength
emitted! by! light-source! 70.! There! is! no! requirement
that! the! rulings! be! transparent! to! light! from! diode-
laser! array 50. Crossings! of! rulings! 92! of! strip! 90
10 are! detected! and! electronically! processed! in! the
manner! described! above! with! reference! to! the
apparatus! and! method! of FIG. 2. A crossing! can! be
detected! as! a! reduction! in! light! detected! by! a
detector 72 or! 74,! for! example,! in! the! case! of! dark
15 lines! on! a! bright! background,! or! as! an! increase! in
the! detected! light,! for! example **in** the! case! of! bright
lines! on! a! dark! background.

Typically,! the! method! of! FIG.! 8! is! practiced! by
an! operator! holding! strip! 90! in! position! on! skin 48
20 with! one! hand! and! moving! handpiece 32Y with! the! other
hand. As! depicted! in! FIGS.! 9-11,! two! position
sensors! 41! may! be! provided,! with! apertures! of! one
sensor! on! one! side! of! tip 34Y and! apertures! of! the
other! sensor! on! the! other! side! of! tip 34Y. Selective
25 activation! of! one! or! the! other! of! the! sensors
provides! for! right! or! left! hand! operation! of
handpiece 32Y.

It! should! be! noted! here,! that! while! position
sensors! 41! are! described! above! with! reference! to! a
30 remote! light-source! and! detectors! optically
communicating! with! sensor! apertures! by! means! of
optical! fibers,! this! should! not! be! considered! as! a
limiting! configuration! for! such! sensors. By! way! of
example,! in! a! handpiece! similar! to! handpiece 32Y, a
35 position! sensor,! logically! functioning! as! described
above,! may! be! incorporated! in! a! block! of! similar! size

and! similarly! position! to! block! 100,! with! the! light-
source! and! detectors! of! the! sensor! incorporated! in! a
single! semiconductor! chip.

5 The! method! of! FIG.! 8,! using! a! separate! guide
strip! rather! than! lines! drawn! on! skin! 48,! permits
that! a! position! sensor! may! function! by! means! other
than! optical. By! way! of! example,! a! guide! strip! may
be! provided! with! magnetized! rulings! or! indicia.! This
10 may! be! in! the! form! of! a! preferentially! magnetized
strip! of! a! form! similar! to! that! on! credit! cards! and
the! like,! or! rulings! in! a! magnetic! medium! on! a! strip
of! a! non-magnetic! material.! One! preferred! sensor! for
such! indicia! would! include! at! lest! one! and! preferably
15 two! (for! direction! sensing)! magnetic! pickup! heads
located! in! a! block! of! similar! size! and! position! to
block! 100. The! two! pickup! heads! would! provide! for! a
direction-sensing! capability! as! described! above! for
sensor! 41. In! another! example,! rulings! or! indicia! 92
20 may! be! in! the! form! of! depressions! in! (or! protrusions
above)! the! upper! surface! of! guide! strip! 90! with! the
indicia! being! sensed! by! two! styli! located! in! a! block
of! similar! size! and! position! to! block! 100.

One! advantage! of! the! method! of! FIG.! 8,! whether
optical,! magnetic! or! mechanical! indicia! are! used,! is
25 that! higher! sensing! resolution! is! possible! compared
with! the! sensing! resolution! obtainable! in! the! method
of! FIG.! 2.! The! higher! resolution! permits! a! closer
spacing! of! indicia,! which! is! of! particular! advantage
in! sensing! the! speed! of! movement! of! the! handpiece,
30 and! even! allows! a! determination! of! whether! the! speed
of! movement! is! increasing! or! decreasing.

Regarding! speed! of! movement! of! the! handpiece,
as! discussed! above,! there! are! two! primary! criteria
which! may! determine! a! maximum! possible! speed! of
35 movement! for! the! handpiece.! One! of! these! criteria! is
the! maximum! possible! firing! rate! of! the! laser,! the

other! is! the! rate! at! which! chilled! lens! 58! can
adequately! cool! skin 48. Should! the! latter! be! the
limiting! criterion,! the! limitation! can! be! overcome! by
pre-cooling! an! untreated! sub-area! of! skin 48 while! an
5 adjacent! sub-area! of! the! skin! is! being! treated.
Referring! to! FIGS.! 9-11,! one! preferred! means! of
effecting! such! a! pre-cooling! is! to! provide! a! pre-
cooling! plate 104 of! about! the! same! area! as,! and
adjacent! to,! lens! 58! and! about! level! with! contact
10 surface! 59! thereof.

Pre-cooling! plate! 104! is! preferably! formed! from
a! material! having! a! high! coefficient! of! thermal
conductivity! such! as! copper.! If! copper! is! selected,
it! is! preferable! that! it! be! coated! or! plated! with! a
15 hard! corrosion-resistant! material,! for! example,
nickel! or! rhodium.! In! handpiece 32Y, pre-cooling
plate 104 is! completely! cooled! by! attaching! it! in
thermal! contact! with! cooling! jacket 62 (not! visible
in! FIGS.! 9-11). Those! skilled! in! the! art! may! devise
20 other! arrangements! for! cooling! pre-cooling! plate! 104
without! departing! from! the! spirit! and! scope! of! the
present! invention. Provision! of! the! pre-cooling
plate! reduces! the! amount! of! cooling! which! must! be
provided! by! chilled! lens! 58,! and! can! thus! permit! a
25 speed! of! movement! up! to! the! laser! firing! rate! limit
for! apparatus! 30.

Referring! now! to! FIG.! 12! and! FIG.! 13,! still
another! automatic! firing! apparatus! and! method! in
accordance! with! the! present! invention! includes
30 placing! a! ruled! guide! strip! 91,! on! edge,! in! contact
with! skin! to! be! treated,! and! sensing! crossings! of
rulings! 92! thereon! using! a! side-looking! position
sensor! incorporated! in! a! handpiece! 32W! in! accordance
with! the! present! invention.! The! side-looking
35 position! sensor! is! similar! to! above-described
sensor! 41! with! the! exception! that! transmitting

aperture! 76! and! receiving! apertures! 78! and! 80! thereof
face! in! a! direction! parallel! to! the! plane! of! skin
being! treated. Apertures! 76,! 78! and! 80! are! located
in! block! 110! attached! to! a! lateral! extension! 112! of
handpiece! 32W.

In! one! preferred! example! of! operation! of
handpiece! 32,! guide! strip! 91! is! made! from! translucent
material! having! opaque! rulings! 92,! and! handpiece! 32W
is! moved,! with! sensor! block! 110! thereof! in! contact
with! guide-strip! 91. Line-crossing! detection! occurs
in! the! manner! described! above! with! respect! to
sensor! 41! of! handpiece! 32.! Alternatively,! the! guide-
strip! could! be! made! of! a! reflecting! material! such! as
a! metal! and! having! a! plurality! of! slots! machined
therein! to! define! the! rulings.! In! this! case,! a! drop
in! detected! light! intensity! would! correspond! to! a
line! crossing.

Two! position! sensors! with! apertures! thereof! on
opposite! sides! of! handpiece! 32W! may! be! individually,
selectively! activated! to! provide! for! right! or! left
hand! operation! of! the! handpiece! as! discussed! above
with! reference! to! handpiece! 32Y.! Sensing! methods! are
not! limited! to! optical! methods! as! described! but! may
include! magnetic! and! mechanical! methods **as** discussed
above.

A! particular! advantage! of! the! guide! strip
arrangement! of! handpiece! configuration! of! FIGS.! 12
and! 13! is! that! relative! vertical! motion
(perpendicular! to! skin! 48)! between! the! handpiece! and
the! guide! strip! is! possible! while! still! maintaining
sensor! apertures! 76,! 78! and! 80! in! contact! with! the
ruled! surface! of! the! guide! strip.! This! is
particularly! advantageous! when! treating! skin! of! a
strongly! contoured! body! member! such! as! a! knee.
Adding! an! additional! sensor! 41R! on! one! or! both! sides
of! handpiece! 32W! (see! FIG.! 12)! provides! that! rotary

motion! of! the! handpiece,! in! a! direction! indicated! by
arrows! E,! can! be! detected.! This! can! provide! an
operator! with! a! warning! should! the! handpiece! be
inadvertently! inclined! in! direction! E! to! a! degree
5 which! would! compromise! proper! therapeutic! treatment.

Referring! now! to! FIG.! 14,! FIG.! 15,! FIGS.! 15A-D
and! FIG.! 16,! another! handpiece! 32R! in! accordance! with
the! present! invention! is! configured! for! automatic
firing! without! the! need! for! a! separate! guide-strip! or
10 markings! ruled! on! skin! to! be! treated.! Handpiece! 32R
includes! a! wheel! or! roller! 120! which! rotates! about! an
axle! 122! extending! from! tip! 34R! of! the! handpiece! (see
FIG.! 16).

Roller! 120! is! arranged! to! make! contact! with
15 skin! 48! being! treated! when! lens! 58! of! the! handpiece
makes! contact! with! the! skin.! Moving! the! handpiece! in
the! (longitudinal)! direction! indicated! by! arrows! A
causes! roller! 120! to! rotate.! Roller! 120! includes
radial! markings! or! indicia! 124! on! the! side! thereof
20 facing! handpiece! 32R.! Indicia! 124! have! equal! angular
spacing. Handpiece! 32R! includes! a! position! sensor! 41
having! side-looking! apertures! 76,! 78! and! 80
positioned! to! detect! motion! of! indicia! 124! in! the
manner! described! above! in! which! similar! sensors
25 detect! motion! of! a! handpiece! over! fixed! indicia.

The! angular! spacing! of! indicia! 124! may! be
selected! such! that! peripheral! spacing! of! the! indicia
on! roller! 120! is! equal! to,! or! some! sub-multiple! of,
the! length! of! lens! 58.! Sensor! 41! can! thereby! provide
30 signals! for! automatic! firing! and! speed! of! movement
calculation! as! described! above. Alternatively,! the
spacing! may! be! reduced! to! the! point! where! the! line
spacing! is! relatively! small! compared! with! the! length
of! the! lens,! for! example,! about! equal! to! a! line! width
35 or! less! such! that.! In! this! case,! with! revolution! of
roller! 120,! sensor! 41! generates! a! stream! of! signals

similar to those generated by a conventional shaft encoder. This would allow automatic firing to be effected at any predetermined interval simply by correspondingly programming control electronics of console 38.

Preferably, rotary motion of roller 120 is damped such that the roller can not continue to rotate if contact thereof with skin 48 is lost. This provides that signals from sensor 41 can be used to determine loss of contact of handpiece 32R with skin 48. As an alternative or backup, however, another sensor 41C (see FIGS. 15, FIG. 15A, FIG. 15B, 15C and 16) can be provided, the purpose of which is only to sense contact, or loss thereof, with skin 48.

Contact sensor 41C is similar to above described position sensor 41 except for the arrangement of light delivery optical fiber 76 and light receiving fibers 78 and 80 in a block 100C (see FIGS. 15A-B for details) for holding the ends of the optical fibers in alignment with each other. In block 100C the relative angle between the fibers is about the same as for those of above-described sensor 41 but with the angular subtense diverging at the distal ends of the fibers rather than converging. This is achieved by crossing the receiving fibers 78 and 80 in block 100C and arranging transmitting fiber 76 to bisect the angle between the receiving fibers.

A result of this arrangement is that the amount of scattered light received by the receiving fibers is somewhat reduced compared with the arrangement of sensor 41. The possibility of receiving fibers 78 and 80 receiving light from optical fiber 76 by any optical mechanism other than volume scatter through skin 48 is essentially eliminated. Because of this,

the effectiveness of sensor 41C as a skin-contact sensor is increased compared with that of sensor 41.

Referring to FIG. 15C, where this arrangement functions as a skin-contact sensor only, it is possible to use a sensor block 100D which includes only a sending fiber 76 and a receiving fiber 78. This allows a greater angular divergence between the sending and receiving fibers. In FIG. 15D is schematically depicted the output of a detector cooperative with a sensor head 100D when the sensor head (the distal tips of fibers 76 and 78) is at distances of between 0.0 and 3.0 mm for surfaces of opaque grey plastic (curve F) light-colored skin (curve G) and translucent white plastic (curve H). About 0.5 milliwatts (mW) of light at a wavelength of about 660 nm is delivered from optical fiber 76. Optical fibers 76 and 78 each have a diameter of 1.0 mm and are inclined at 40° from vertical, i.e., with an angle of 80° therebetween. The tips of the optical fibers are laterally and longitudinally separated by 2.0 mm. It can be seen that there is essentially zero detector output from the opaque grey plastic surface at any distance up to contact. A similar result was obtained on a rough (diffusely reflecting) steel surface.

For skin (skin of a finger in this experiment) and translucent plastic, output increases gradually as the sensor approaches the surfaces. Applying a force of 10.0 grams (g) to the sensor head on the skin surface caused the detector output to rise sharply from about 18.0 to 29.5, indicating the effectiveness of the sensor head as a contact sensor. A further increase in force provided no significant increase in output. In practice, a threshold level of detection can be set at the detector output level at skin contact. It is a relatively simple matter to

provide! a! calibration! capability,! via! a! potentiometer
or! the! like,! to! adjust! the! threshold! for! different
skin! shades. Contact! of! the! sensor! head,! or! lack
thereof,! can! then! be! determined! according! to! whether
5 the! detector! output! is! above! or! below! the! set
threshold! level.

Referring! now! to! FIG.! 17! and! FIG.! 18,! another
handpiece! 32E! in! accordance! with! the! present
invention! includes! a! wheel! or! roller! 130.! Roller! 130
10 is! rotatable! on! an! axle! 132! which! extends! through! a
bearing! housing! 134! into! an! extended! portion! 37! of
tip! 34E! of! handpiece! 32E.! Axle! 132! engages! a! shaft
encoder! 136! located! in! extended! portion! 37! of
tip! 34E.

Roller! 130! is! arranged! to! make! contact! with
skin! 48! being! treated! when! lens! 58! of! the! handpiece
makes! contact! with! the! skin.! Moving! the! handpiece! in
the! (longitudinal)! direction! indicated! by! arrows! A
causes! roller! 130! to! rotate.! Rotation! of! roller! 130
20 is! monitored! by! shaft! encoder! 136.! Signals! from
shaft! encoder! 136! representative! of! the! angular
position! or! degree! of! rotation! of! roller! 130! are
transmitted! to! control! electronics! in! control
console! 38! (see! FIG.! 1)! and! used! for! triggering
25 automatic! firing! and! computing! speed! of! motion! of! the
roller. Making! or! breaking! contact! with! skin! 48! by
tip **34E** of! handpiece! 32E! can! be! detected! by! the
control! electronics! detecting! respectively! initiation
and! termination! of! rotation! of! roller! 130! via! signals
30 from! shaft! encoder! 136.! Alternatively! or
additionally,! an! optical! skin! contact! sensor! of! the
type! described! above! with! reference! to! handpiece! 32R
may! be! provided.

Referring! now! to! FIG.! 19,! FIG.! 20! and! FIG.! 21,
35 another! handpiece! 32H! in! accordance! with! the! present
invention! is! illustrated. Handpiece! 32H! includes! a

detachable! housing! 121! (shown! in! phantom! in! FIG.! 21)
which! attaches! to! tip! 34! of! the! handpiece.

Detachable! housing! 121! includes! a! wheel! or! roller! 123
arranged! to! engage! skin! 48! being! treated! when! lens! 58
5 of! tip! 34! is! placed! in! contact! with! the! skin.

Roller! 123! includes! a! series! of! equally-spaced,
parallel! (paraxial)! longitudinal! rulings! 125! around! a
cylindrical! surface! of! the! roller! (see! FIG.! 20) .! The
spacing! of! the! rulings! is! preferably! equal! to! or! some
10 sub-multiple! of! the! length! of! lens! 58! for! reasons
discussed-above,! for! example,! with! reference! to
handpiece! 32R. Alternatively! the! lines! may! be! set
sufficiently! close! together! that! the! roller! and
detector! function! in! the! manner! of! a! conventional
15 shaft! encoder! as! discussed! above.

A! sensor! block! 127! including! distal! ends! of
optical! fibers! 76,! 78! and! 80! of! a! position! sensor! 41
is! located! on! tip! 34 of! handpiece! 32H! (see! FIG.! 21) .
Here,! the! distal! ends! of! the! fibers! are! arranged! in! a
20 vertically-oriented! line! such! that! the! position
sensor! can! detect! the! passage! of! rulings! 125! of
roller! 123! as! the! roller! rotates! responsive! to! motion
of! the! handpiece! over! skin! 48.! From! the! detection! of
rulings,! the! position! of! handpiece! 32H! on! skin! 48! can
25 be! determined! as! discussed! above.

Referring! to! FIG.! 20A,! an! alternative
roller! 123A! for! handpiece! 32H! is! illustrated.
Roller! 123A! comprises! two! coaxial! cylindrical
portions! 129! and! bounding! a! cylindrical! portion! 131
30 coaxial! therewith! but! having! a! lesser! diameter! than
cylindrical! portions! 129. Here,! paraxial! rulings! 125
are! made! on! cylindrical! portion! 131. This! helps
minimize! contact! with! the! rulings! on! contacting
skin! 48! when! roller! 123A! contacts! skin! 48! via
35 cylindrical! portions! 129! thereof. Contact! of
rulings! 125! with! skin! 48! could! progressively! lead! to

contamination with skin grease, skin debris and the like. Such contamination could lead to errors in the accuracy of position determination by position sensor 41.

5 Sensor handpiece 32H is described above as including a position sensor 41 having a light-source and detectors thereof located in the body of the handpiece and connected to a sensor block by optical fibers. Those skilled in the art will recognize
10 however that a similarly functioning sensor head could be positioned in detachable housing 121 without departing from the spirit and scope of the present invention. In fact it is possible to locate all components of a position detector in detachable
15 housing 121, requiring only an electrical connection with the body of the handpiece for power and data communication.

 It is pointed out here that indicia on any above-described rollers may be dark lines on a bright.
20 background or bright lines on a dark background. Alternatively, the indicia may be fluorescent, or may be magnetic if sensor 41 is replaced with a magnetic pick-up arrangement.

 Referring now to FIG. 22, another handpiece 32T
25 in accordance with the present invention includes a transponder 140 and a receiver 142. Preferably, transponder 140 is an ultrasonic emitter and receiver 142 is an ultrasonic detector. Transponder 140 sends a signal-pulse (dashed
30 line 144) to a screen or wall 146 located proximate a patient 148 on whose back skin 48 is being treated. Here, screen 146 is shown mounted on a table 150 on which patient 148 is lying in a face-down position.

 Receiver 142 receives an echo (a return-pulse)
35 of the signal-pulse sent by transponder 140 (dashed line 152) from screen 146. Control electronics of

console! 38,! connected! to! transducer! 140! and
receiver! 142! record! the! time! of! sending! signal-
pulse! 144! and! time! of! receiving! echo! 152
corresponding! thereto! and! determine! a! time! difference
5 between! the! sending! and! receiving.! The! time
difference! between! the! sending! of! signal-pulse! 144
and! the! receiving! of! echo! 152! provides! a! measure! of
the! position! of! handpiece! 32T! with! respect! to
screen! 146! and,! accordingly,! with! respect! to
10 patient! 148! as! the! handpiece! is! moved! in! a
longitudinal! direction! indicted! by! arrows! A. These
position! measurements! are! used! by! control! electronics
of! console! 38! to! automatically! trigger! firing! of! the
laser! at! equal! position! increments! of! handpiece! 32,
15 and,! optionally,! to! monitor! the! speed! of! motion! of
handpiece! 32T! as! discussed! above! with! reference! to
other! embodiments! of! the! apparatus! and! method! of! the
present! invention.

It! should! be! noted! here! that! the! treatment
20 illustrated! in! FIG.! 22! and! the! position! of! screen 146
with! respect! to! patient 148 are! merely! exemplary.
Those! skilled! in! the! art! may! devise! other! screen
locations! adapted! to! other! treatments! without
departing! from! the! spirit! and! scope! of! the! present
25 invention.

It! should! also! be! noted! that! while! an! ultrasonic
emitter! and! receivers! are! preferred! in! the! above
described! embodiment! of! the! present! invention,! the
operating! principles! of! this! embodiment! are
30 applicable! if! transponder 140 (and! corresponding
receivers 142) rely! on! sending! and! detection! of
signals! other! than! ultrasonic! signals.! By! way! of
example,! these! may! be! optical! signals! (pulses)
generated! by! a! laser,! forming! in! effect! a! laser
35 rangefinder. The! laser! may! be! located! in,! or! on,
handpiece! 32T,! or! may! be! remote! therefrom! with

radiation! from! the! laser! being! delivered! to
transponder! 140! by! an! optical! fiber.! The! signals! may
also! be! radar! signals! (pulses)! with! transponder! 140
being! a! miniature,! (for! example! incorporated! in! a
5 semiconductor! chip)! radar! transmitter. In! the! case
of! optical! or! radar! signals,! electronic! processing! of
the! signals! may! prove! to! be! more! complex! than! for
ultrasonic! signals,! because! of! the! relatively! short
distances! traversed! by! signal! pulses! and,
10 correspondingly,! the! relatively! very! short! time
between! sending! and! detection! thereof.

Referring! now! to! FIG.! 23,! another! handpiece 32D
in! accordance! with! the! present! invention! includes! a
transponder 160. Preferably,! transponder 160 is! an
15 ultrasonic! emitter. Transponder 160 sends! a! signal-
pulse! (dashed! lines! 162)! radiating! therefrom! in! a
diverging! manner! to! three! receivers! 164,! preferably
ultrasonic! detectors! incorporated! in! a! video! display
unit (VDU)! 166 having! a! display! 168.! Here,! VDU! 166
20 is! shown! positioned! proximate! table! 150! on! which
patient 148, on! whose! back! skin 48 is! being! treated,
is! lying! in! a! face-down! position.

In! one! example! of! signal! processing! for! the
arrangement! of! handpiece 32D and! receivers! associated
25 therewith,! for! each! signal-pulse! the! difference! in
arrival! time! at! each! the! receivers! is! recorded.
Based! on! this! difference! in! arrival! time,! and! on! the
spacing! of! the! receivers,! control! electronics
associated! with! the! transponder! and! receivers
30 determine,! by! triangulation,! a! position! in
longitudinal! direction! A! and! lateral! direction! B! for
transponder! 160! relative! to! a! plane! in! which! the
receivers! are! located. Here! the! plane! is! of! the
front! of VDU 166. **This position measurement** is! used
35 by! control! electronics! of! console 38 to! automatically
trigger! firing! of! the! laser! depending! on! its! lateral

and! longitudinal! position. A! visual! record! of! the
firings! is! presented! on! display! 168.

It! should! be! noted! here! that,! in! theory! at
least,! only! two! detectors! are! necessary! to! provide
5 two dimensional! position! location! for! the! handpiece.
Providing! three! detectors! can! increase! the! accuracy
of! two! dimensional! position! location! and! also! provide
information! on! position! in! a! third! (perpendicular! to
the! general! plane! of! the! skin)! direction.! This
10 information! can! be! useful! if! a! contoured! area! of
skin,! for! example,! a! knee,! is! being! treated.

In! one! example! of! operation! of! handpiece 32D,
point! 170P! on! patient! 148! designates! the! lower! left-
hand! corner! (origin)! of! an! area! of! skin! 48! to! be
15 treated. This! area! is! considered! to! be! divided! into
a! series! on! sub-areas! equal! in! dimension! to! lens! 58
of! handpiece 32D. Point! 170D! on! display! 168! is
electronically! arranged! to! represent! point! 170P! on
patient! 48.

20 The! instantaneous! position! of! handpiece! 32D
relative! to! point! 170P! is! indicated! on! display! 168! by
a! square! "cursor"! 169! having! dimensions! representing
the! area! treatable! in! a! single! firing! of! the! laser.
Treatment! is! initiated! by! placing! tip! 34! of
25 handpiece! 32D! in! contact! with! skin! 48! of! patient! 148
and! activating! trigger! 36! of! the! handpiece! to! begin
automatic! firing.

Each! successful! firing! is! recorded! on
display! 169! as! a! solid! square,! thereby! providing! a
30 direct! indication! of! progress! of! then! treatment! and
of! any! areas! such! as! an! area! 171! which! may! have! been
"missed". Control! electronics! may! also! be! arranged
to! store! an! electronic! map! of! successful! firings.
The! stored! electronic! map! can! be! used! by! the! control
35 electronics! to! automatically! fire! the! laser! when! the
position! detection! system! senses! that! the! handpiece

tip! is! contacting! the! skin! in! a! missed! area.! The
stored! electronic! map! can! be! also! be! used! by! the
control! electronics! to! prevent! manual! firing! of! the
laser! if! the! handpiece! tip! is! in! contact! with! the
5 skin! in! an! area! that! has! already! been! successfully
treated.

It! should! be! noted! here! that! receivers **164** are
shown! integrated! into **VDU! 166** as! one! convenient
location! for! the! detectors.! Receivers **164** may! also
10 be! located! remote! from **VDU! 166** and! supported! on! a
separate! frame! and! locations! may! be! varied! according
a! specific! treatment.! Such! locations! may! be! selected
and! varied! without! departing! from! the! spirit! and
scope! of! the! present! invention.

15 While! preferred! embodiments! of! the! present
invention! are! described! above! with! reference! tracking
motion! of! a! handpiece! in! which! a! laser! source! is
located,! the! present! invention! is! not! limited! to! use
with! such! a! handpiece.! Principles! of! the! application
20 are! also! applicable! to! a! handpiece! which! delivers
radiation! received! from! a! remotely! located! source! of
laser-radiation. Such! a! handpiece,! for! example,! may
receive! radiation! from! the! remote! source! via! an
optical! fiber! of! bundle! of! optical! fibers! or! via! a
25 hollow! articulated! arm.! Further,! principles! of! the
present! invention! are! equally! applicable! if! treatment
does! not! require! that! the! tip! or! delivery! aperture! of
the! handpiece! is! in! contact! with! skin! being! treated.
By! way! of! example,! the! tip! may! include! a! lens! for
30 shaping! or! focussing! the! delivered! radiation! and! may
be! spaced! at! a! relatively! short! distance! (about! one
or! two! centimeters)! from! the! skin! with! spacing! being
maintained! by! an! open! jig! in! contact! with! the! skin.

It! should! also! be! noted! that! automatic! firing! in
35 accordance! with! the! present! invention! has! been
described! with! reference! to! controlling! firing! such

that! sub-areas! treated! in! a! single! filing! are! "tiled"
together! more! or! less! contiguously! to! cover! a! total
area! to! be! treated,! any! of! the! above! described
embodiments! to! covering! an! area! by! overlapping
5 treated! sub-areas! in! a! predetermined! pattern.! By! way
of! example,! each! treated! (in! a! single! firing)! sub-
area! may! overlap! the! previously! treated! sub-area! by
half! the! length! of! the! sub-area.! This! may! be! done
for! example! to! avoid! the! possibility! of! any! narrow
10 untreated! areas! being! left! between! treated! sub-areas.

Generally,! the! present! invention! is! described
and! depicted! herein! in! terms! of! a! preferred! and! other
embodiments. The! invention,! however,! is! not! limited
by! those! embodiments! described! and! depicted. Rather,
15 the! invention! is! limited! only! by! the! claims! appended
hereto.

WHAT IS CLAIMED IS:

1. A method of treating an area of skin with a laser by delivering a series of laser-radiation pulses to the skin, each of the laser pulses treating a sub-area of the area to be treated, the method comprising the steps of:

(a) providing a laser which, on being fired, generates a pulse of laser-radiation;

(b) providing a handpiece for delivering a pulse of laser-radiation from said laser to the skin being treated;

(c) while moving the handpiece over the skin being treated, electronically determining the location of said handpiece in the area of skin being treated; and

(d) automatically firing the laser when said electronically determined location corresponds to a sub-area to be treated.

2. The method of claim 1 wherein said location determining step (c) comprises the steps of (i) providing a plurality of regularly spaced indicia on or adjacent the area of skin being treated (ii) providing at least one sensor on the handpiece said sensor arranged to detect passage of the handpiece by one or more of said indicia as the handpiece is moved over the skin being treated and wherein in step (d) said automatic firing is triggered by the passage of the handpiece by one or more of said indicia.

3. The method of claim 2, wherein said indicia are one of graphic indicia, magnetic indicia, and mechanical indicia.

4. The method of claim 3 wherein said indicia are graphic indicia.

5. The method of claim 4, wherein said sensor includes a light-source arranged to direct light onto the skin being treated such that the thus directed light is scattered by the skin being treated; wherein said sensor includes one or more light detectors arranged to detect said scattered light; wherein said graphic indicia are equally-spaced parallel lines drawn on the area of skin being treated in a medium which is at least partially opaque to the wavelength of light emitted by said light-source and substantially transparent to the wavelength of said pulse of laser radiation; and wherein passage of the handpiece by any one of said indicia results in a reduction in said scattered light detected by said at least one detector, said reduction in scattered light indicating that one of said indicia has been passed.

6. The method of claim 4, wherein said graphic indicia are equally-spaced parallel lines drawn on a strip of material placed on or adjacent to the area of skin being treated; wherein said sensor includes a light-source arranged to direct light onto the strip such that the thus directed light is scattered by the strip; wherein said sensor includes one or more light detectors arranged to detect said scattered light; wherein said strip is diffusely reflective at the wavelength of light emitted by said light-source for said directed light and said lines are drawn in a medium which is absorbent at the wavelength of light emitted by said light-source; and wherein passage of the handpiece by any one of said indicia results in a reduction in said scattered light detected by said at least one detector, said reduction in scattered light indicating that one of said indicia has been passed.

7. The method of claim 4, wherein said graphic indicia are equally-spaced parallel lines drawn on a strip of material placed on or adjacent to the area of skin being treated; wherein said sensor includes a light-source arranged to direct light onto the strip; wherein said strip is absorbent at the wavelength of light emitted by said light-source and said lines are drawn in a medium which is diffusely reflective at the wavelength of light emitted by said light-source; wherein said sensor includes one or more light detectors arranged to detect directed light diffusely reflected by said lines; and wherein passage of the handpiece by any one of said indicia results in an increase in light detected by said at least one detector, said increase in detected light indicating that one of said indicia has been passed.

8. The method of claim 4, wherein said graphic indicia are equally-spaced parallel lines drawn on a strip of material placed on or adjacent to the area of skin being treated; wherein said sensor includes a light-source arranged to direct light onto the strip; wherein said lines are drawn in a medium which is fluorescent on irradiation with light emitted by said light-source; wherein said sensor includes one or more light detectors arranged to said fluorescence; and wherein passage of the handpiece by any one of said indicia results in increase in light detected by said at least one detector, said increase in detected light indicating that one of said indicia has been passed.

9. The method of claim 3 wherein said indicia are magnetic indicia

10. The method of claim 3 wherein said indicia are mechanical indicia.

11. The method of claim 2 wherein said indicia are spaced apart by a distance equal to one of a linear dimension of the sub-area irradiated by said laser pulse; a distance equal to a sub-multiple of a linear dimension of the sub-area irradiated by said laser pulse; and a distance relatively small compared with a linear dimension of the sub-area irradiated by said laser pulse.

12. The method of claim 1 wherein said location determining step (c) comprises the steps of (i) providing a roller on the handpiece, said roller arranged to contact the skin being treated and rotate in response to the handpiece being moved over the skin being treated, and said roller having a plurality of regularly spaced indicia thereon (ii) providing at least one sensor on the handpiece said sensor arranged to detect passage by said sensor of one or more of said indicia as said roller rotates and wherein in step (d) said automatic firing is triggered by the passage by said sensor of one or more of said indicia.

13. The method of claim 12, wherein said indicia are radially extending lines on a side of said roller.

14. The method of claim 13, wherein said indicia are spaced apart at the periphery of said roller by a distance equal to one of a linear dimension of the sub-area irradiated by said laser pulse; a distance equal to a sub-multiple of a linear dimension of the sub-area irradiated by said laser

pulse; and a distance relatively small compared with a linear dimension of the sub-area irradiated by said laser pulse.

5 15. The method of claim 12 wherein said indicia are longitudinally extending lines on a first cylindrical surface of said roller.

10 16. The method of claim 15, wherein said indicia are spaced apart at the periphery of said roller by a distance equal to one of a linear dimension of the sub-area irradiated by said laser pulse; a distance equal to a sub-multiple of a linear dimension of the sub-area irradiated by said laser pulse; and a distance relatively small compared with
15 a linear dimension of the sub-area irradiated by said laser pulse.

 17. The method of claim 15 wherein said first cylindrical surface of said roller is a skin contacting surface of said roller.

20 18. The method of claim 15 wherein said roller has a second cylindrical surface for contacting the skin, and first cylindrical surface has a smaller diameter than the diameter of said second cylindrical surface.

25 19. The method of claim 1 wherein said location determining step (c) comprises the steps of (i) providing a roller on the handpiece, said roller arranged to contact the skin being treated and rotate in response to the handpiece being moved over the
30 skin being treated said roller being axially connected to a shaft encoder said shaft encoder

providing! signals! used! for! said! electronic! location
determining.

20. The! method! of! claim! 1! wherein! said! location
determining! step! (c)! comprises! the! steps! of! (i)
5 providing! a! screen! adjacent! the! skin! being! treated
(ii) providing! a! transponder! on! the! handpiece,! said
transponder! arranged! to! emit! a! regular! train! of
signal-pulses! toward! said! screen! such! that! said
signal-pulses! are! incident! thereon! and! a! return-pulse
10 corresponding! to! each! of! said! incident! signal-pulses
returns! to! the! handpiece! (iii)! providing! a! receiver
on! said! handpiece! for! receiving! said! return! pulses
(iv) determining! an! elapsed! time! between! emitting! a
said! signal-pulse! and! receiving! a! said! corresponding
15 return-pulse,! said! elapsed! time! being! representative
of! said! location! of! said! handpiece.

21. The! method! of! claim! 20! wherein! said! signal-
pulses! are! ultrasonic! pulses.

22. The! method! of! claim! 20! wherein! said! signal-
20 pulses! are! optical! pulses.

23. The! method! of! claim! 20! wherein! said! signal-
pulses! are! radar! pulses.

24. The! method! of! claim! 1! wherein! said! location
determining! step! (c)! comprises! the! steps! of! (i)
25 providing! a! transponder! on! the! handpiece,! said
transponder! arranged! to! emit! a! regular! train! of
signal-pulses! each! thereof! in! diverging! beam! (ii)
providing! at! least! two! spaced-apart! receivers! located
in! a! position! remote! from! said! handpiece,! within! the
30 divergence! of! said! beam,! for! receiving! said! signal
pulses! (iii)! based! on! the! spacing! of! said! receivers

and! an! arrival! time! of! said! signal! pulses! at! said
receivers! determining! said! location! of! said! handpiece
in! at! least! length! and! width! dimensions! of! said! area
of! skin! to! be! treated.

5 25. The! method! of! claim! 24! wherein! said! signal-
pulses! are! one! of! ultrasonic! pulses,! optical! pulses,
or! radar! pulses.

26. The! method! of! claim! 25! wherein! said! signal
pulses! are! ultrasonic! pulses.

10 27. The! method! of! claim! 24,! wherein! said! area
of! skin! to! be! treated! is! contoured! and! said! three
spaced! apart! receivers! are! provided,! and! said
location! of! said! handpiece! in! said! area! of! skin! to! be
treated! is! determined! in! length! width! and! height
15 dimensions.

28. The! method! of! claim! 25! wherein! said! signal-
pulses! are! one! of! ultrasonic! pulses,! optical! pulses,..
or! radar! pulses.

20 29. A! method! of! treating! an! area! of! skin! with! a
laser! by! delivering! a! series! of! laser-radiation
pulses! to! the! skin,! each! of! the! laser! pulses! treating
a! sub-area! of! the! area! to! be! treated,! the! method
comprising! the! steps! of:

25 (a) providing! a! laser! which,! on! being! fired,
generates! a! pulse! of! laser-radiation;

 (b) providing! a! handpiece! for! delivering! a! pulse
of! laser-radiation! from! said! laser! to! the! skin! being
treated;

30 (c) while! moving! the! handpiece! over! the! skin
being! treated,! electronically! determining! a! location
of! said! handpiece! in! the! area! of! skin! being! treated

said! location! determining! including! (i)! providing! a plurality! of! regularly! spaced! indicia! on! or! adjacent the! area! of! skin! being! treated,! and! (ii)! providing! at least! one! sensor! on! the! handpiece! said! sensor
5 arranged! to! detect! passage! of! the! handpiece! by! one! or more! of! said! indicia! as! the! handpiece! is! moved! over the! skin! being! treated;! and

(d) automatically! firing! the! laser! on! detection of! passage! of! the! handpiece! by! one! or! more! of! said
10 indicia.

30. The! method! of! claim! 29! wherein! said! indicia are! spaced! apart! by! a! distance! equal! to! one! of! a linear! dimension! of! the! sub-area! irradiated! by! said laser! pulse;! a! distance! equal! to! a! sub-multiple! of! a
15 linear! dimension! of! the! sub-area! irradiated! by! said laser! pulse;! and! a! distance! relatively! small! compared with! a! linear! dimension! of! the! sub-area! irradiated! by said! laser! pulse.

31. The! method! of! claim! 30! wherein! said! indicia are! provided! by! a! grid! of! parallel! lines! drawn! on! the
20 area! of! skin! to! be! treated.

32. The! method! of! claim! 30! wherein! said! indicia are! provided! by! first! and! second! grids! of! parallel lines! drawn! on! the! area! of! skin! to! be! treated,! said
25 second! grid! being! arranged! orthogonal! to! said! first grid,! and! wherein! said! handpiece! is! provided! with! at least! first! and! second! sensors,! said! first! and! second sensors! for! detecting! passage! of! said! handpiece! by lines! in! respectively! said! first! and! second! grids.

33. The! method! of! claim! 30! wherein! said! indicia are! provided! by! a! parallel! rulings! on! a! strip! of
30

material placed on or adjacent the area of skin to be treated.

34. A method of treating an area of skin with a laser by delivering a series of laser-radiation pulses to the skin, each of the laser pulses treating a sub-area of the area to be treated, the method comprising the steps of:

(a) providing a laser which, on being fired, generates a pulse of laser-radiation;

(b) providing a handpiece for delivering a pulse of laser-radiation from said laser to the skin being treated;

(c) while moving the handpiece over the skin being treated, electronically determining a location of said handpiece in the area of skin being treated said location determining including (i) providing a roller on the handpiece, said roller arranged to contact the skin being treated and rotate in response to the handpiece being moved over the skin being treated, and said roller having a plurality of regularly spaced indicia thereon and (ii) providing at least one sensor on the handpiece, said sensor arranged to detect passage by said sensor of one or more of said indicia as said roller rotates; and

(d) automatically firing the laser on detection of passage by the sensor of one or more of said indicia.

35. The method of claim 34, wherein said indicia are radially-extending lines on a side of said roller.

36. The method of claim 35, wherein said indicia are spaced apart at the periphery of said roller by a distance equal to one of a linear

dimension! of! the! sub-area! irradiated! by! said! laser
pulse;! a! distance! equal! to! a! sub-multiple! of! a! linear
dimension! of! the! sub-area! irradiated! by! said! laser
pulse;! and! a! distance! relatively! small! compared! with
5 a! linear! dimension! of! the! sub-area! irradiated! by! said
laser! pulse.

37. The! method! of! claim! 36! wherein! said! indicia
are! longitudinally-extending! lines! on! a! first
cylindrical! surface! of! said! roller.

10

38. The! method! of! claim! 37,! wherein! said
indicia! are! spaced! apart! at! the! periphery! of! said
roller! by! a! distance! equal! to! one! of! a! linear
dimension! of! the! sub-area! irradiated! by! said! laser
15 pulse;! a! distance! equal! to! a! sub-multiple! of! a! linear
dimension! of! the! sub-area! irradiated! by! said! laser
pulse;! and! a! distance! relatively! small! compared! with
a! linear! dimension! of! the! sub-area! irradiated! by! said
laser! pulse.

20 39. A! method! of! treating! an! area! of! skin! with! a
laser! by! delivering! a! series! of! laser-radiation
pulses! to! the! skin,! each! of! the! laser! pulses! treating
a! sub-area! of! the! area! to! be! treated,! the! method
comprising! the! steps! of:

25 (a) providing! a! laser! which,! on! being! fired,
generates! a! pulse! of! laser-radiation;

(b) providing! a! handpiece! for! delivering! a! pulse
of! laser-radiation! from! said! laser! to! the! skin! being
treated;

30 (c) while! moving! the! handpiece! over! the! skin
being! treated,! electronically! determining! a! location
of! said! handpiece! in! the! area! of! skin! being! treated
said! location! determining! including! (i)! providing! a
screen! adjacent! the! skin! being! treated,! (ii)

providing! a! transponder! on! the! handpiece,! said
transponder! arranged! to! emit! a! regular! train! of
signal-pulses! toward! said! screen! such! that! said
signal-pulses! are! incident! thereon! and! a! return-pulse
5 corresponding! to! each! of! said! incident! signal-pulses
returns! to! the! handpiece,! (iii)! providing! a! receiver
on! said! handpiece! for! receiving! said! return! pulses,
and! (iv)! determining! an! elapsed! time! between! emitting
a! said! signal-pulse! and! receiving! a! said
10 corresponding! return-pulse,! said! elapsed! time! being
representative! of! said! location! of! said! handpiece;
and

(d) automatically! firing! the! laser! when! said
electronically! determined! location! corresponds! to! a
15 sub-area! to! be! treated.

40. A! method! of! treating! an! area! of! skin! with! a
laser! by! delivering! a! series! of! laser-radiation
pulses! to! the! skin,! each! of! the! laser! pulses! treating
a! sub-area! of! the! area! to! be! treated,! the! method
20 comprising! the! steps! of:

(a) providing! a! laser! which,! on! being! fired,
generates! a! pulse! of! laser-radiation;

(b) providing! a! handpiece! for! delivering! a! pulse
of! laser-radiation! from! said! laser! to! the! skin! being
25 treated;

(c) while! moving! the! handpiece! over! the! skin
being! treated,! electronically! determining! a! location
of! said! handpiece! in! the! area! of! skin! being! treated
said! location! determining! including! (i)! providing! a
30 transponder! on! the! handpiece,! said! transponder
arranged! to! emit! a! regular! train! of! signal-pulses
each! thereof! in! diverging! beam,! (ii)! providing! at
least! two! spaced-apart! receivers! located! in! a
position! remote! from! said! handpiece,! within! the
35 divergence! of! said! beam,! for! receiving! said! signal

pulses,! and! (iii)! based! on! the! spacing! of! said
receivers! and! an! arrival! time! of! said! signal! pulses
at! said! receivers! determining! said! location! of! said
handpiece! in! at! least! length! and! width! dimensions! of
5 said! area! of! skin! to! be! treated;! and

(d) automatically! firing! the! laser! when! said
electronically! determined! location! corresponds! to! a
sub-area! to! be! treated.

41. The! method! of! claim! 40,! wherein! said! area
10 of! skin! to! be! treated! is! contoured! and! three! spaced-
apart! receivers! are! provided,! and! said! location! of
said! handpiece! in! said! area! of! skin! to! be! treated! is
determined! in! length! width! and! height! dimensions.

42. A! method! of! treating! an! area! of! skin! with! a
15 laser! by! delivering! a! series! of! pulses! of
electromagnetic! radiation! to! the! skin,! each! of! the
electromagnetic! radiation! pulses! treating! a! sub-area-
of! the! area! to! be! treated,! the! method! comprising! the
steps! of:

20 (a) providing! a! source! of! electromagnetic
radiation! which,! on! being! fired,! generates! a! pulse! of
electromagnetic! radiation;

(b) providing! a! handpiece! for! delivering! a! pulse
of! electromagnetic! radiation! from! said! source! thereof
25 to! the! skin! being! treated;

(c) while! moving! the! handpiece! over! the! skin
being! treated,! electronically! determining! the
location! of! said! handpiece! in! the! area! of! skin! being
treated;! and

30 (d) automatically! firing! the! source! of
electromagnetic! radiation! when! said! electronically
determined! location! corresponds! to! a! sub-area! to! be
treated.

43. In an apparatus for skin treatment using electromagnetic radiation, the apparatus including a source of the electromagnetic radiation and a handpiece cooperative therewith for delivering the electromagnetic radiation to skin being treated, the electromagnetic radiation being delivered by the handpiece through a transparent applicator therein, the applicator being in contact with the skin being treated during treatment, a method of sensing that the applicator is in contact with the skin, the method comprising the steps of:

(a) providing a light-source having an exit-aperture thereof on the handpiece, said exit-aperture configured to be in contact with the skin being treated when the applicator is in contact with the skin being treated;

(b) delivering light from said light-source via said exit-aperture thereof such that, when the applicator is one of proximate the skin or in contact with the skin, light delivered from said exit-aperture is transported laterally through the skin via volume scattering of said light;

(c) providing a detector having a receiving-aperture on said handpiece proximate said light-source exit-aperture;

(d) monitoring the output of said detector; and

(e) interpreting said monitored detector-output as an indication that the applicator of said handpiece has made or lost contact with the skin being treated.

44. A laser system for treating tissue comprising:

a laser for generating laser light;

a! delivery! device! including! a! manually
movable! handpiece! for! delivering! the! laser! light
to! the! tissue;

5 a! sensor! associated! with! the! handpiece! for
monitoring! the! movement! of! the! handpiece! with
respect! to! the! tissue,! said! sensor! generating
output! signals;! and

10 a! processor! for! controlling! the! triggering
of! the! laser! in! response! to! the! receipt! of! the
output! signals! in! a! manner! to! facilitate! uniform
treatment! of! the! tissue! over! a! large! area! with
the! laser! light.

45. A! laser! system! as! recited! in! claim! 44
further! including! ruled! indicia! spatially! associated
15 with! the! tissue! to! be! treated! and! wherein! the! sensor
is! mounted! on! the! handpiece! in! a! manner! to! detect
said! indicia! as! the! handpiece! is! moved! thereby.

46. A! laser! system! as! recited! in! claim! 45
wherein! said! indicia! are! formed! by! one! of:

20 a) markings! directly! on! the! tissue! to! be
treated;! and

b) markings! on! a! rule! located! proximate! the
surface! of! the! skin.

47. A! laser! system! is! recited! in! claim! 46
25 wherein! said! indicia! are! graphic! and! said! sensor
detects! the! indicia! optically.

48. A! laser! system! as! recited! in! claim! 47
wherein! said! sensor! includes! a! light! source! aimed! at
said! indicia,! said! sensor! further! including! a
30 photodetector! configured! to! monitor! changes! in! light
caused! by! the! presence! of! the! indicia.

49. A laser system as recited in claim 44 wherein said sensor includes a wheel rotatably mounted to the handpiece, said wheel rotating in response to the movement of the handpiece across the tissue and wherein said sensor monitors the rotation of the wheel.

50. A laser system as recited in claim 49 wherein the wheel includes ruled indicia which are monitored by the sensor.

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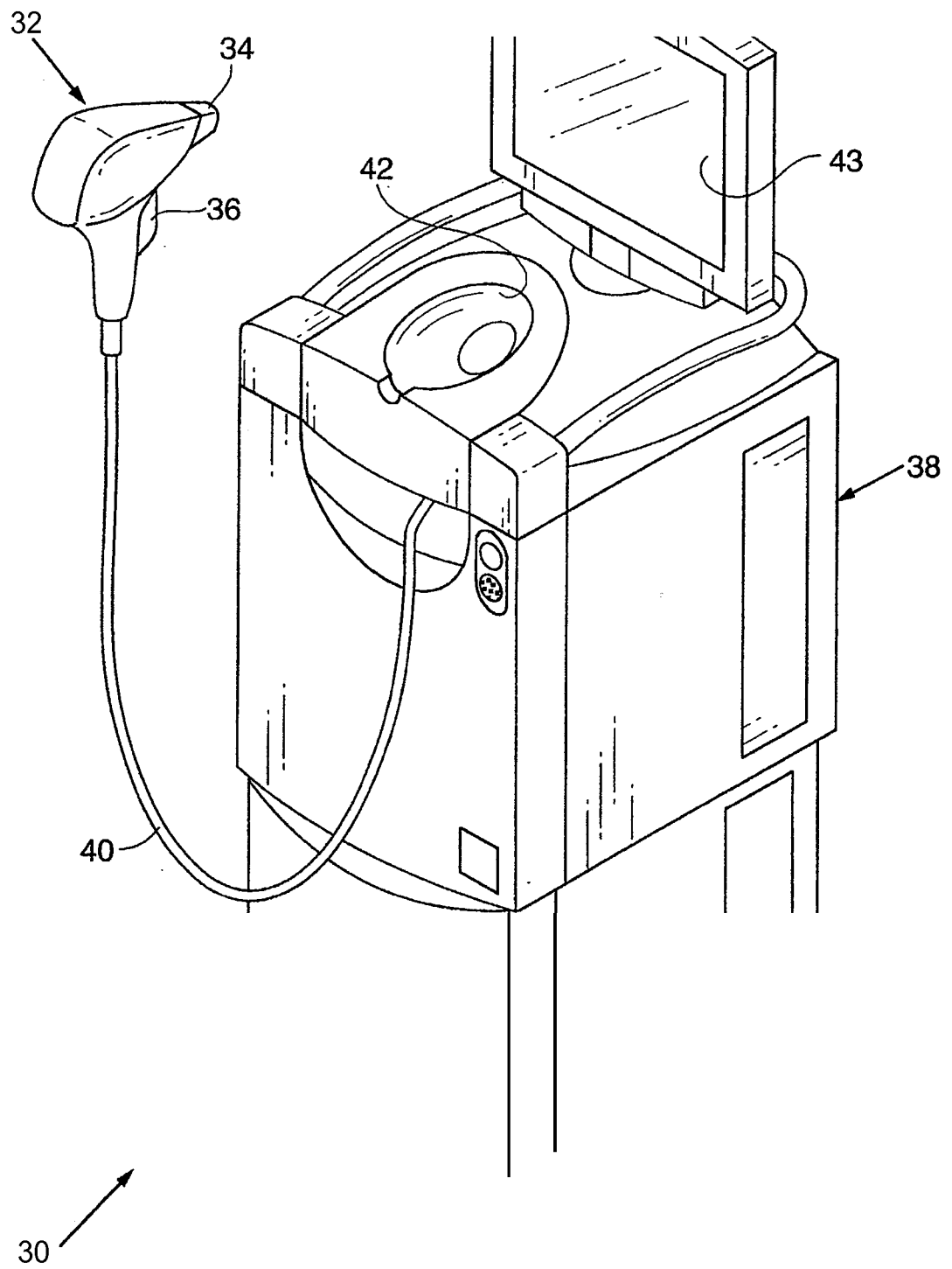


FIG. 1

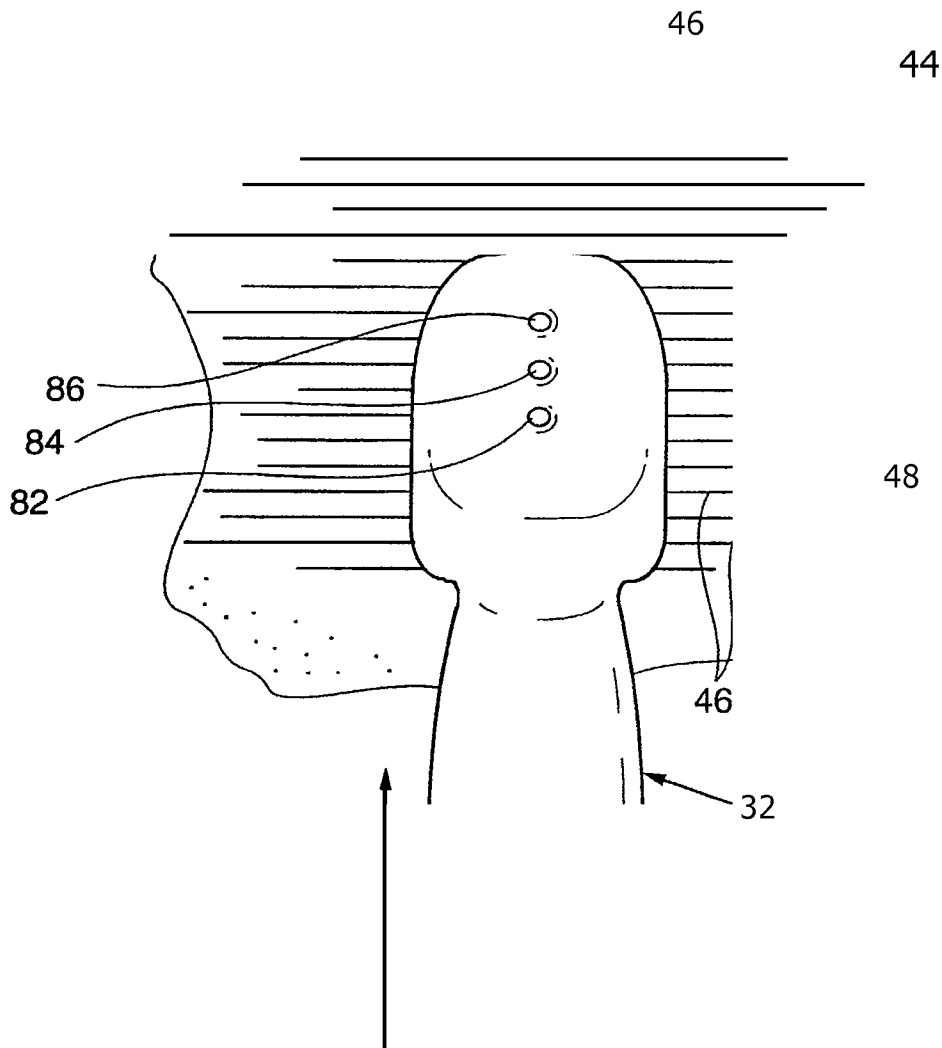


FIG. 2

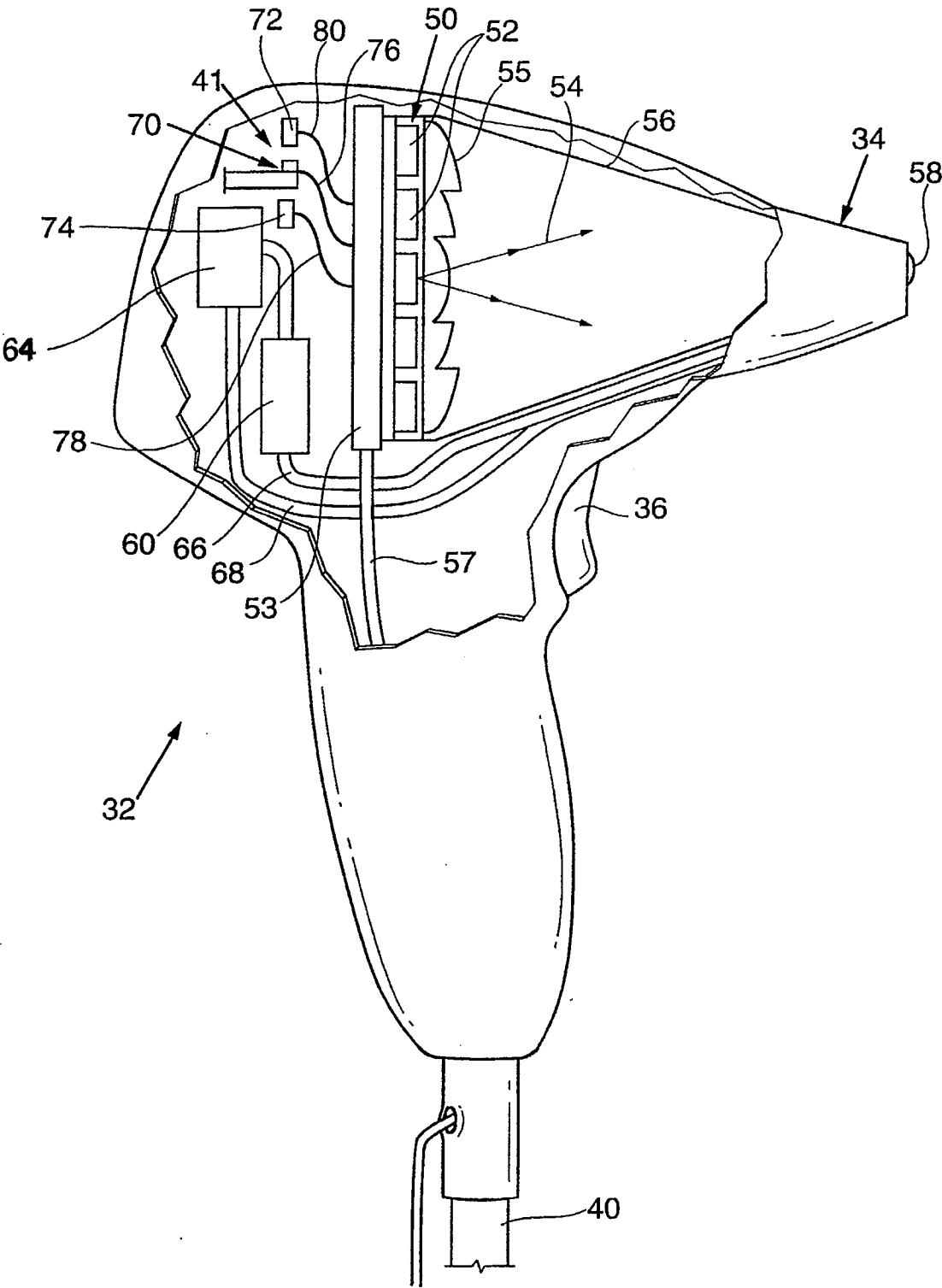


FIG. 3

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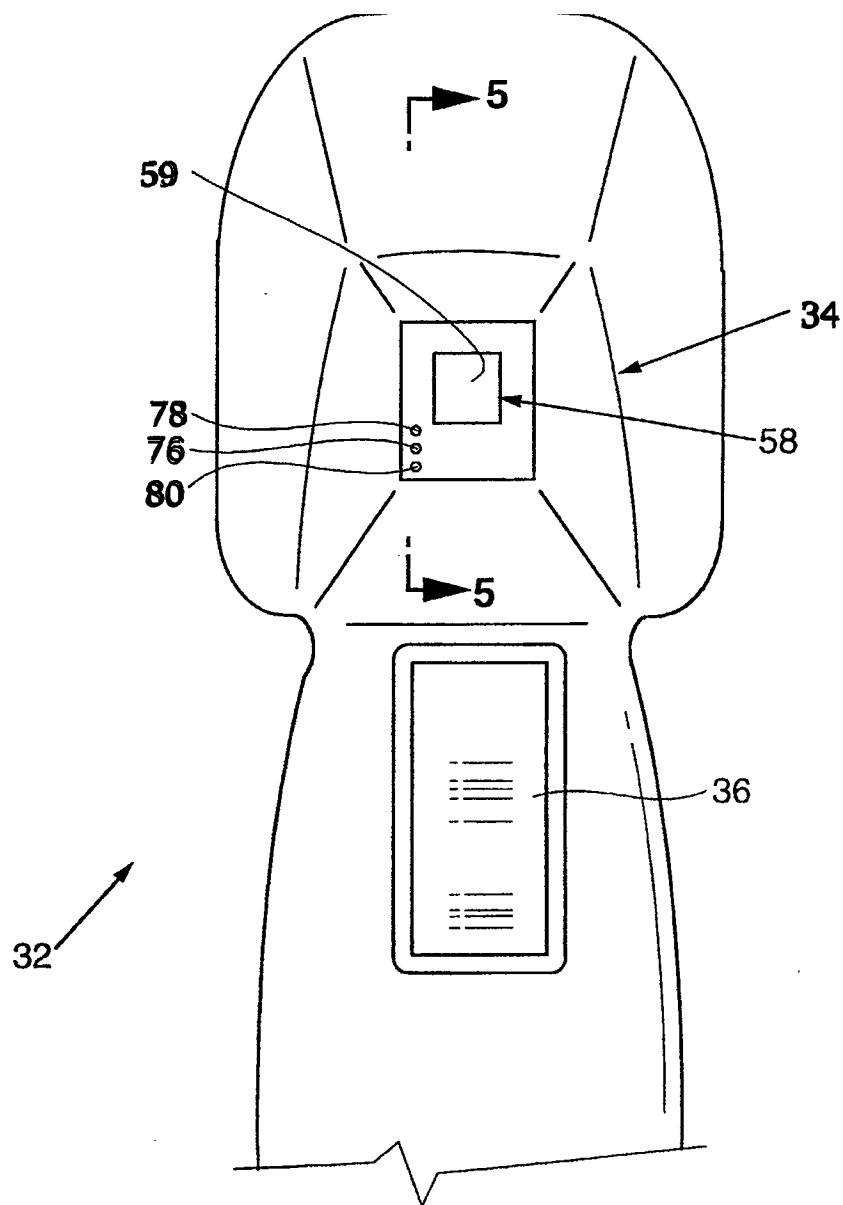
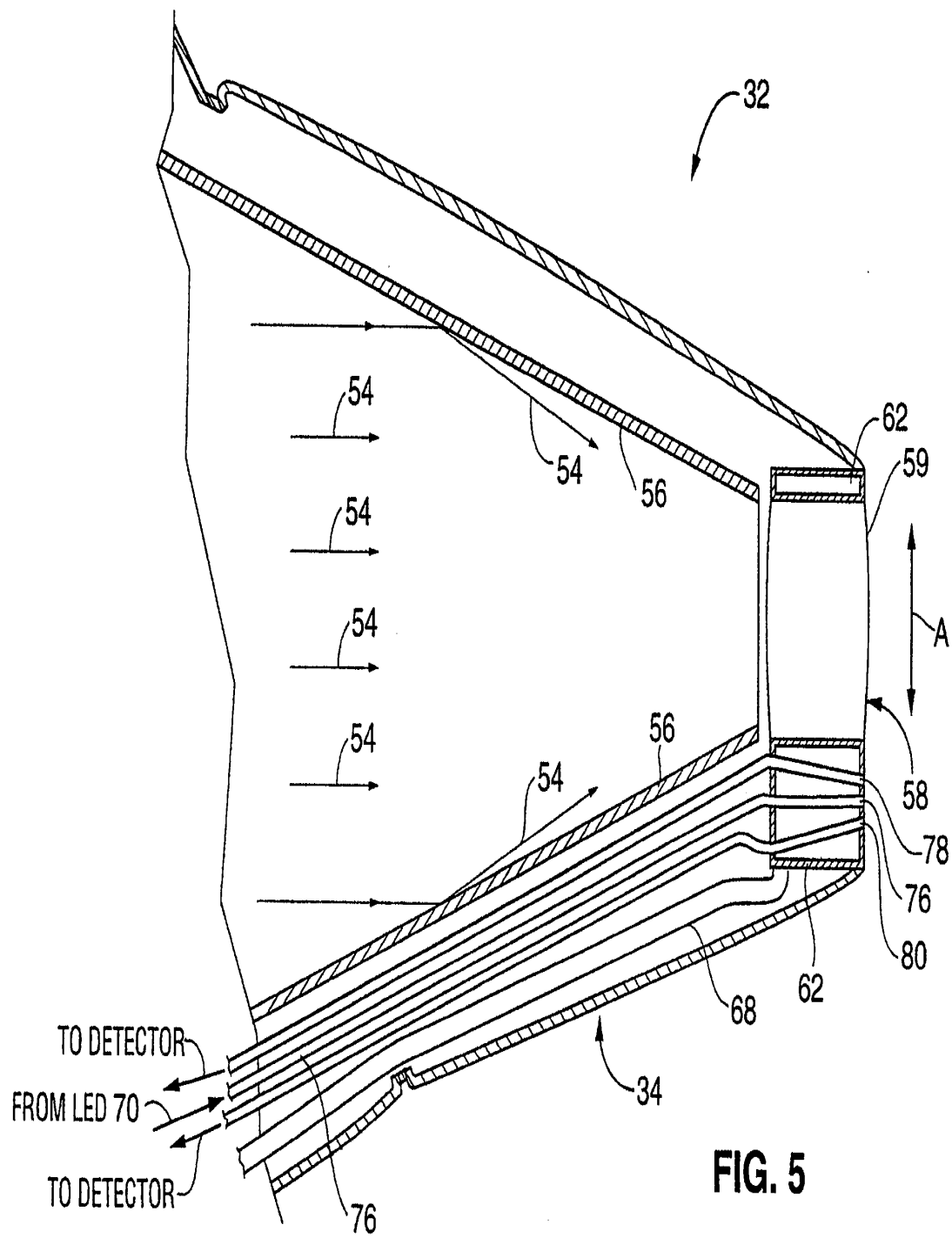


FIG. 4



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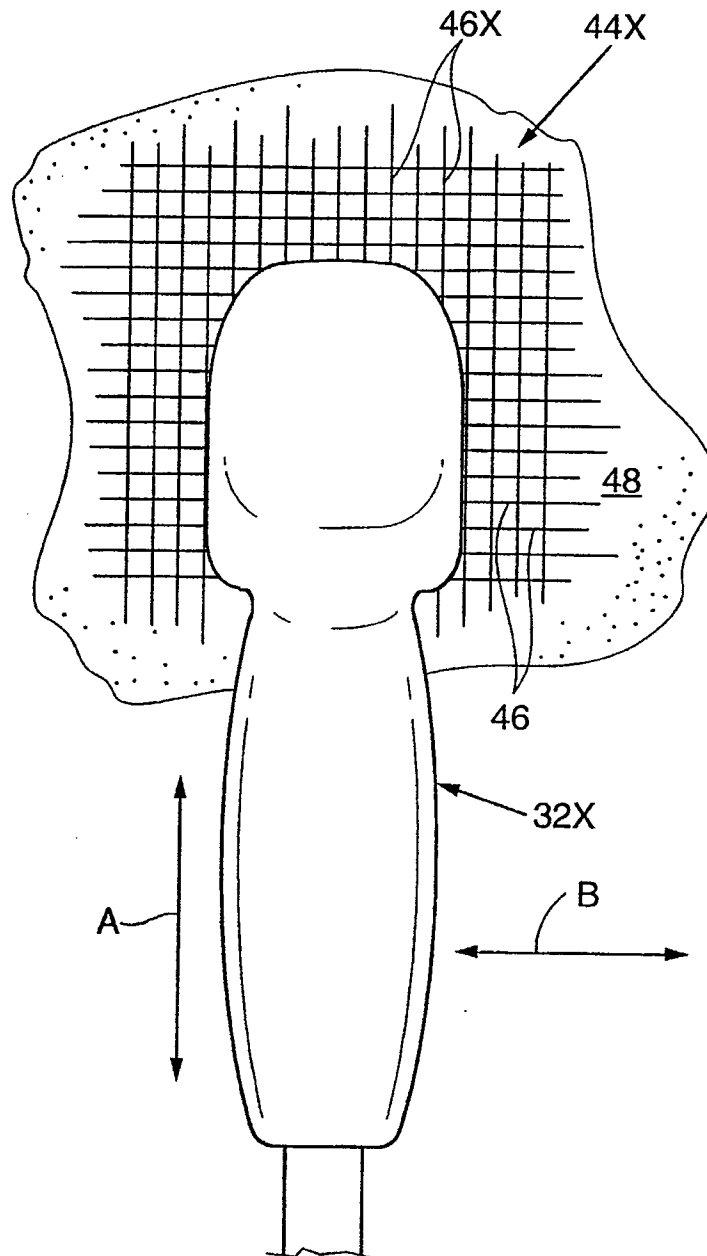
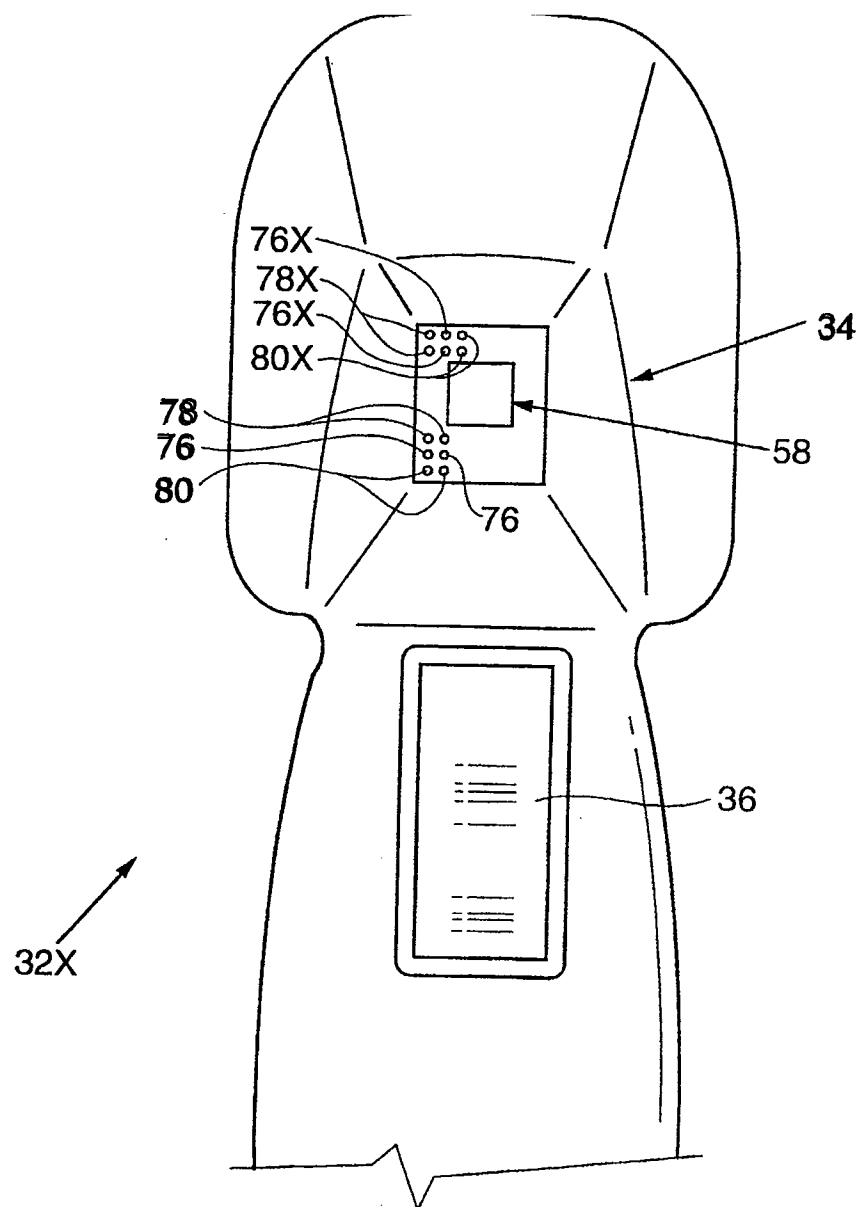


FIG. 6

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**FIG. 7**

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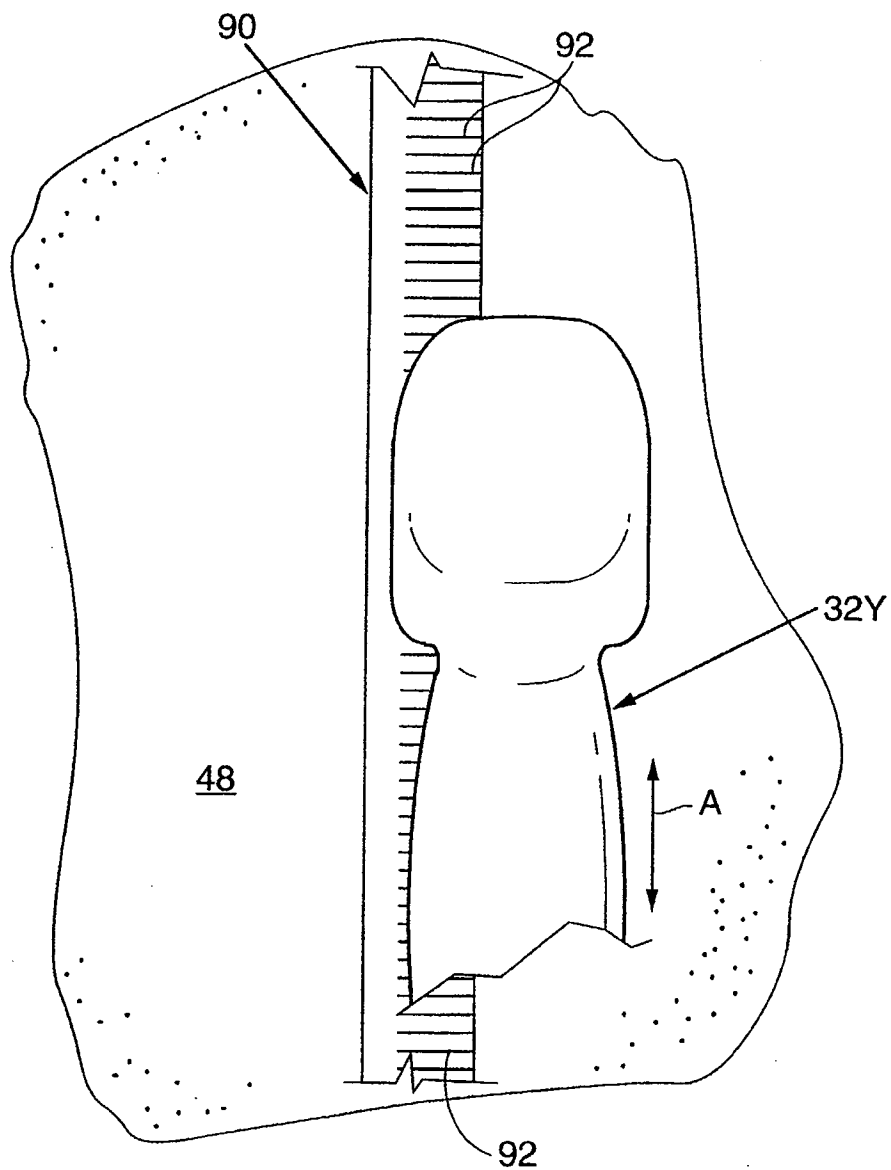


FIG. 8

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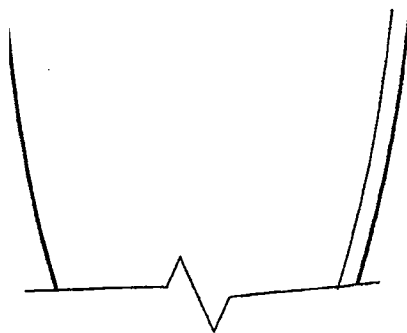
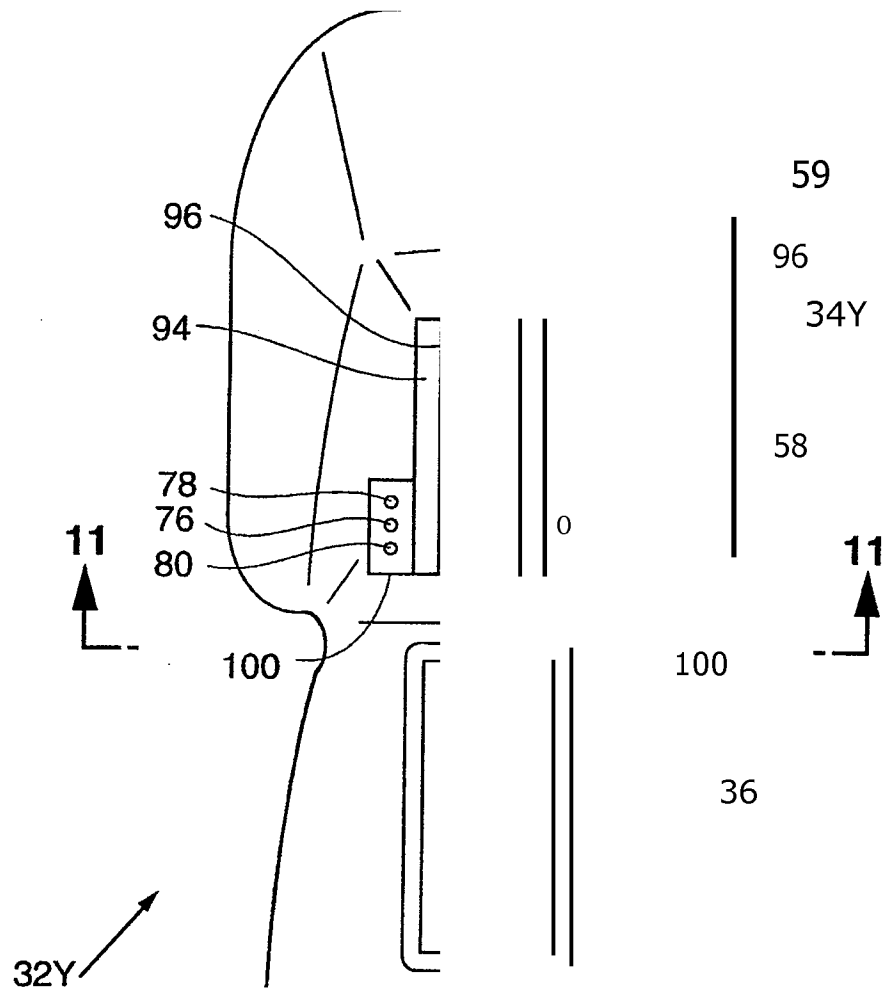


FIG. 9

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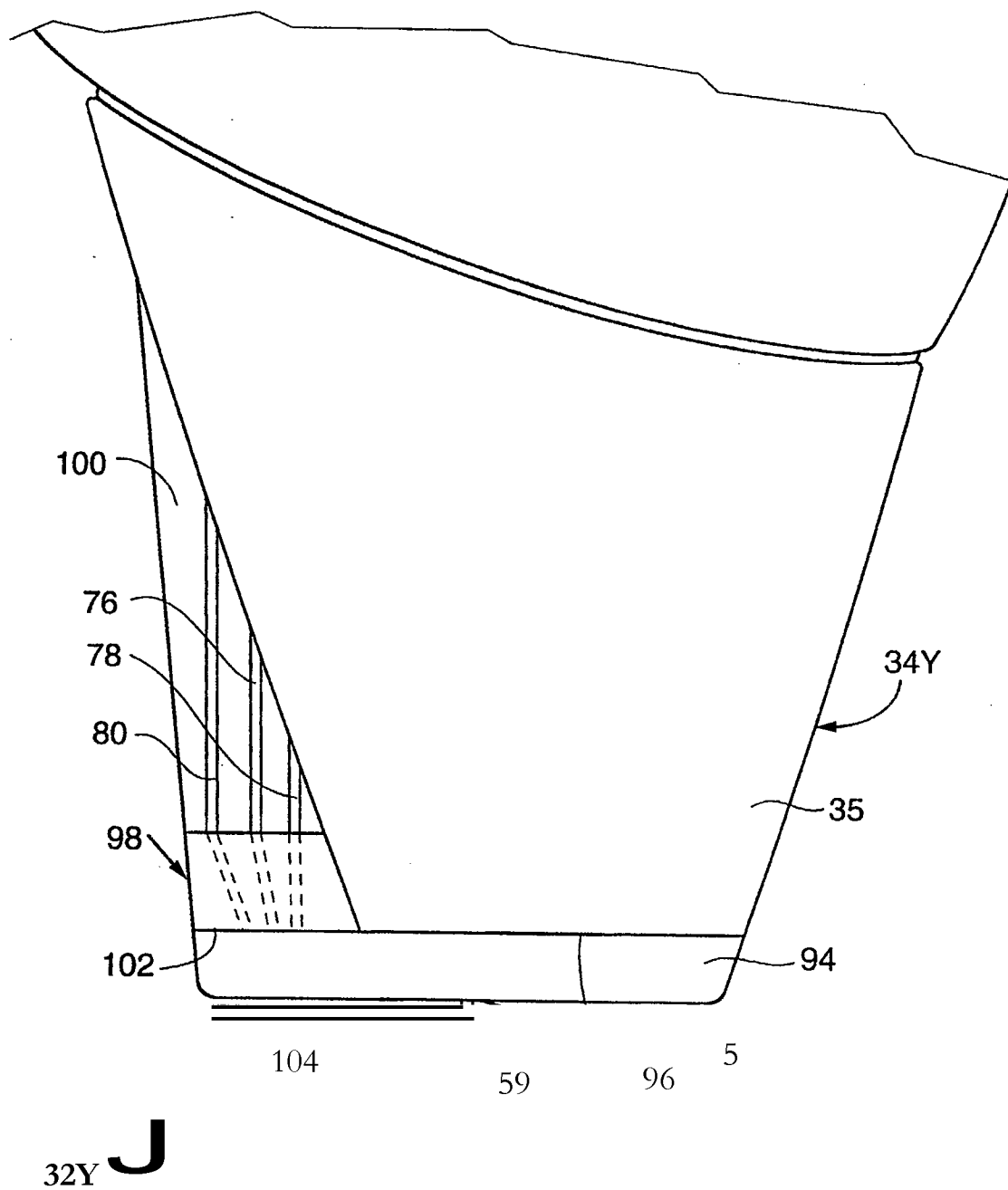


FIG. 10

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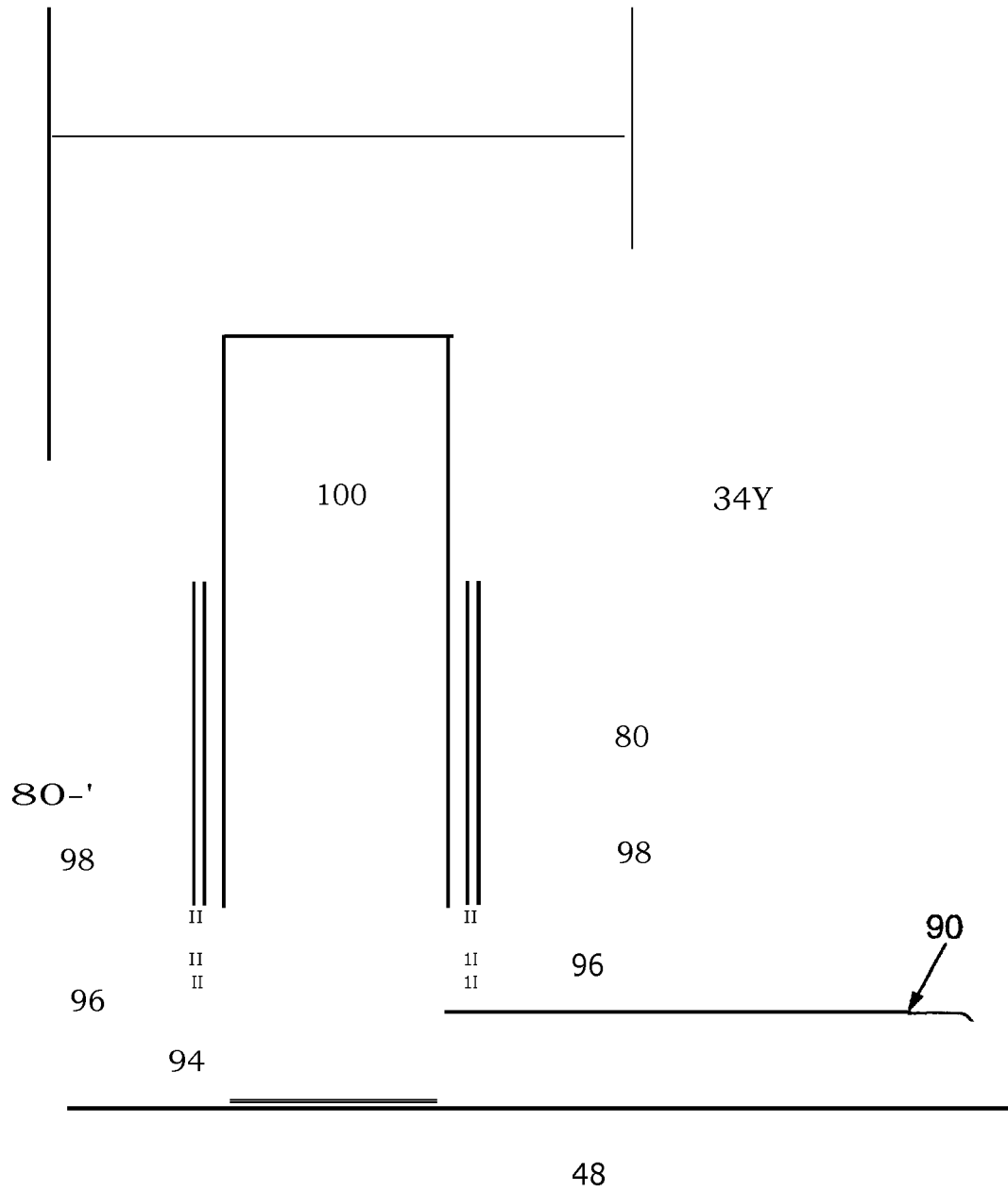


FIG. 11

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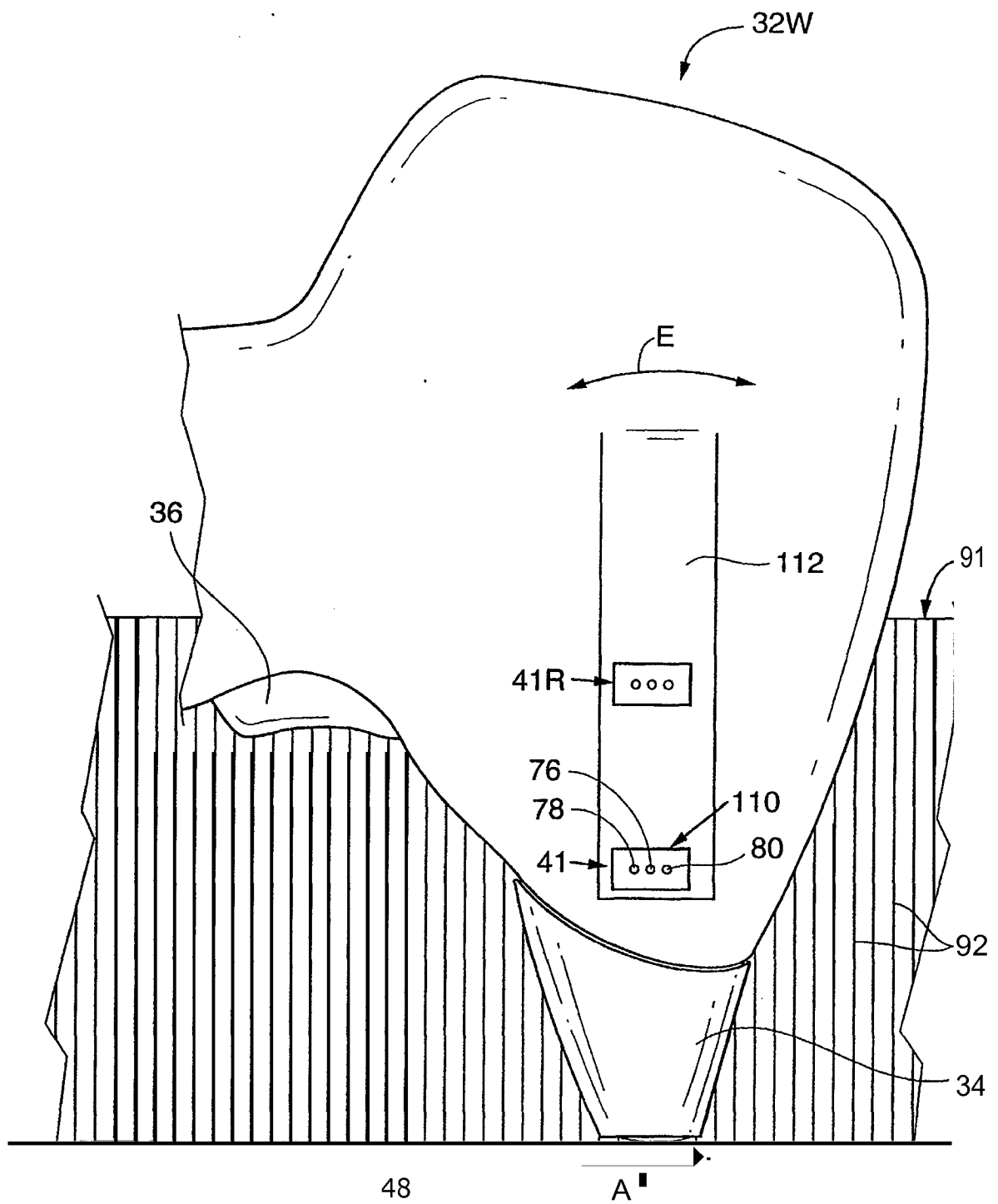


FIG. 12

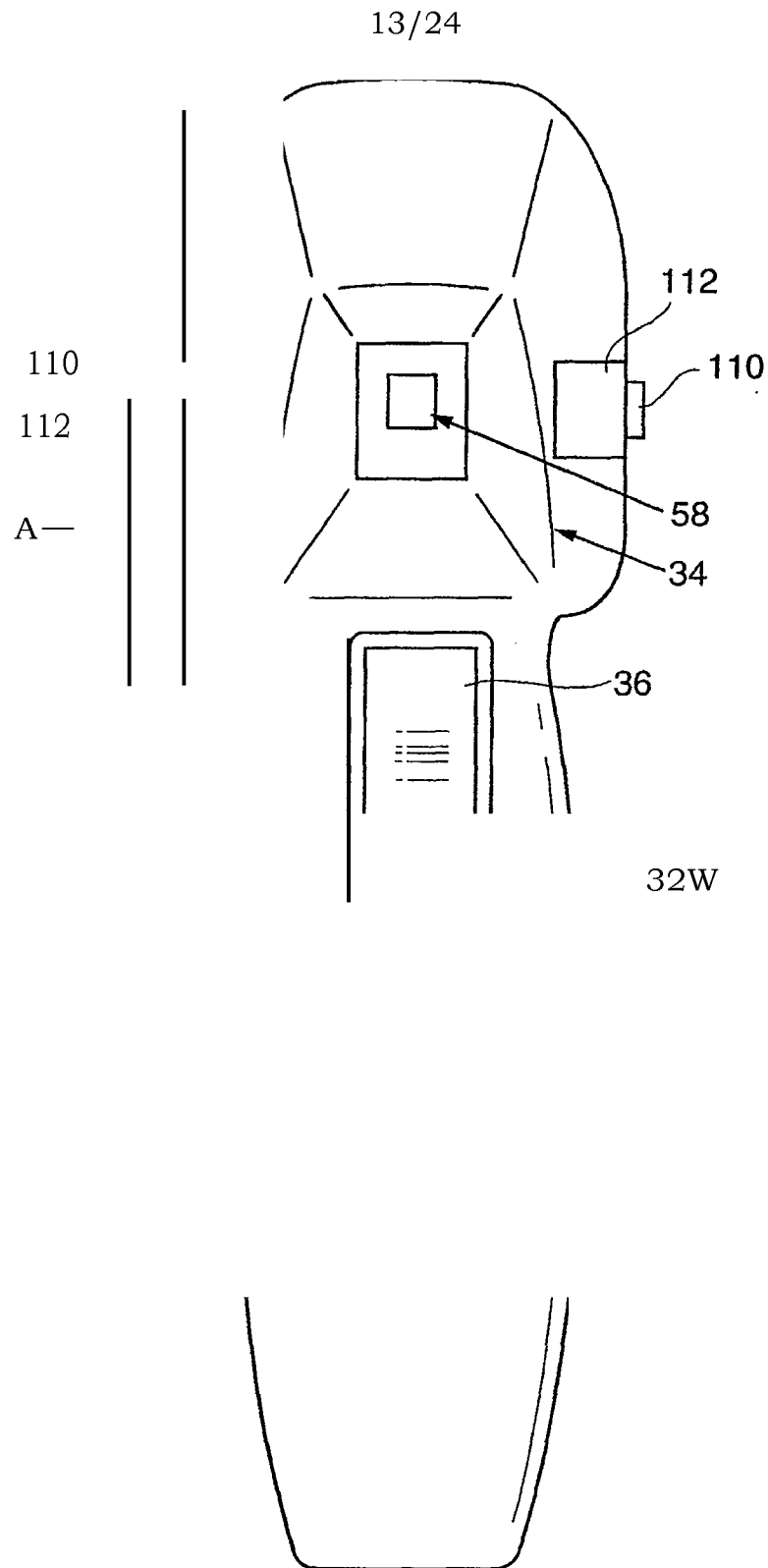


FIG. 13

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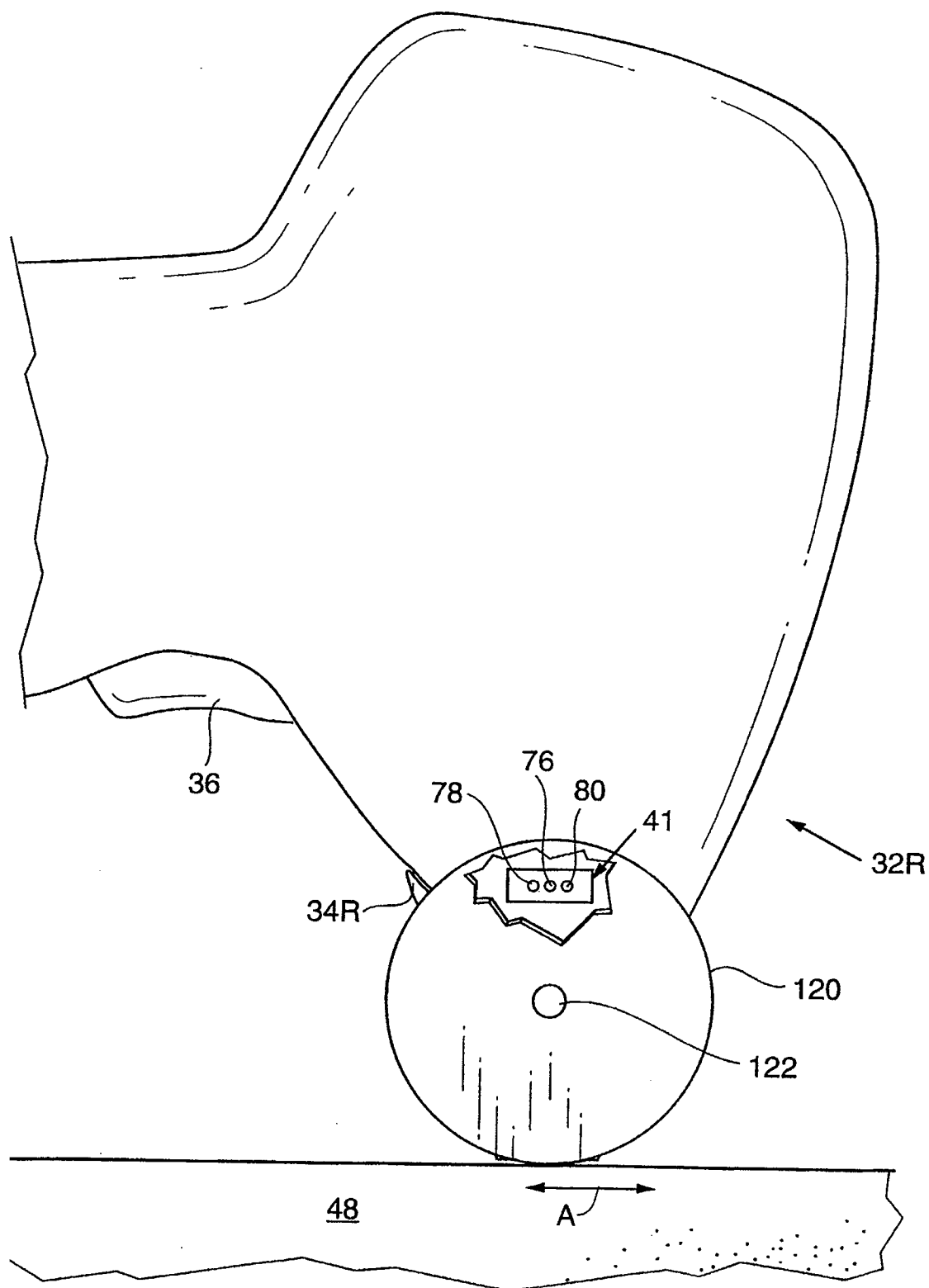


FIG. 14

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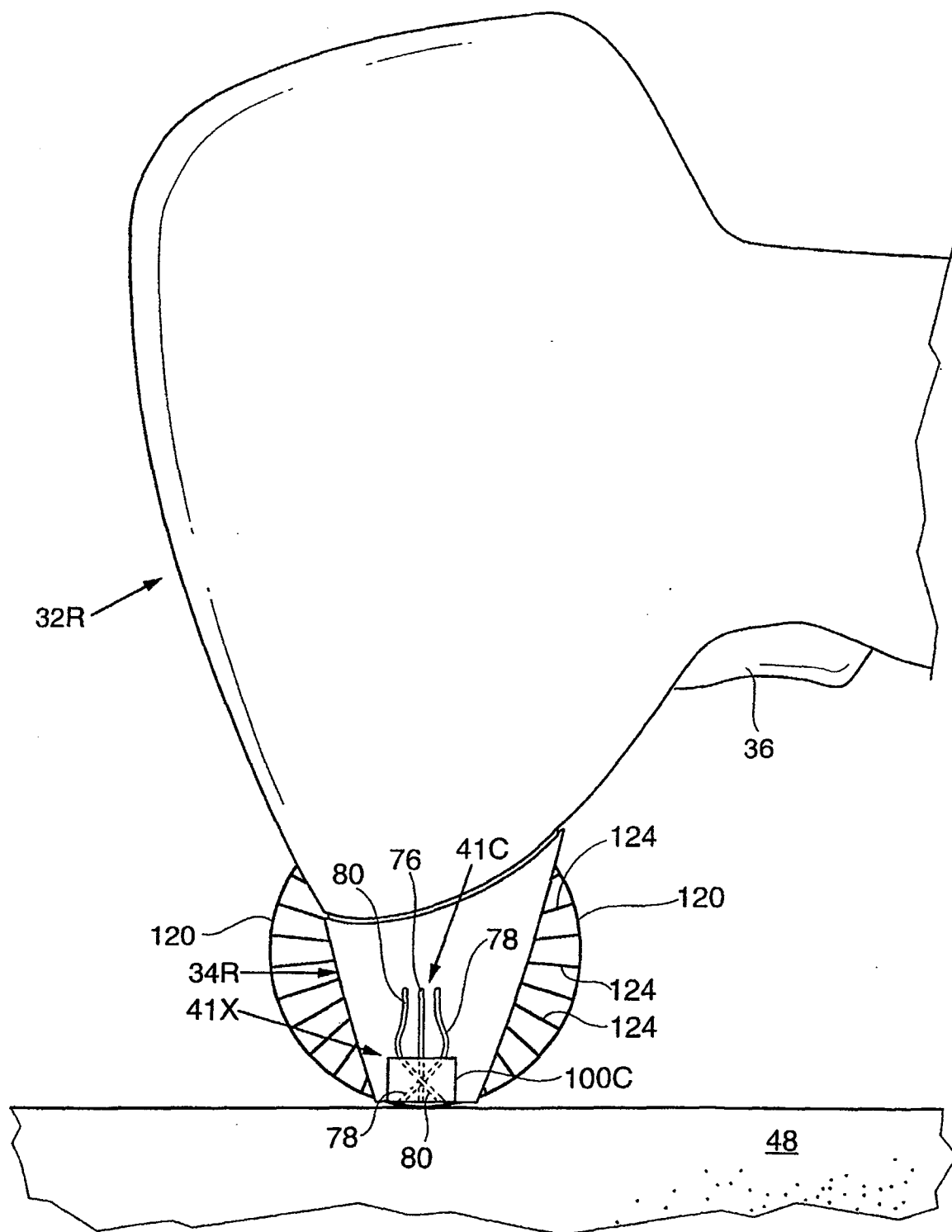


FIG. 15

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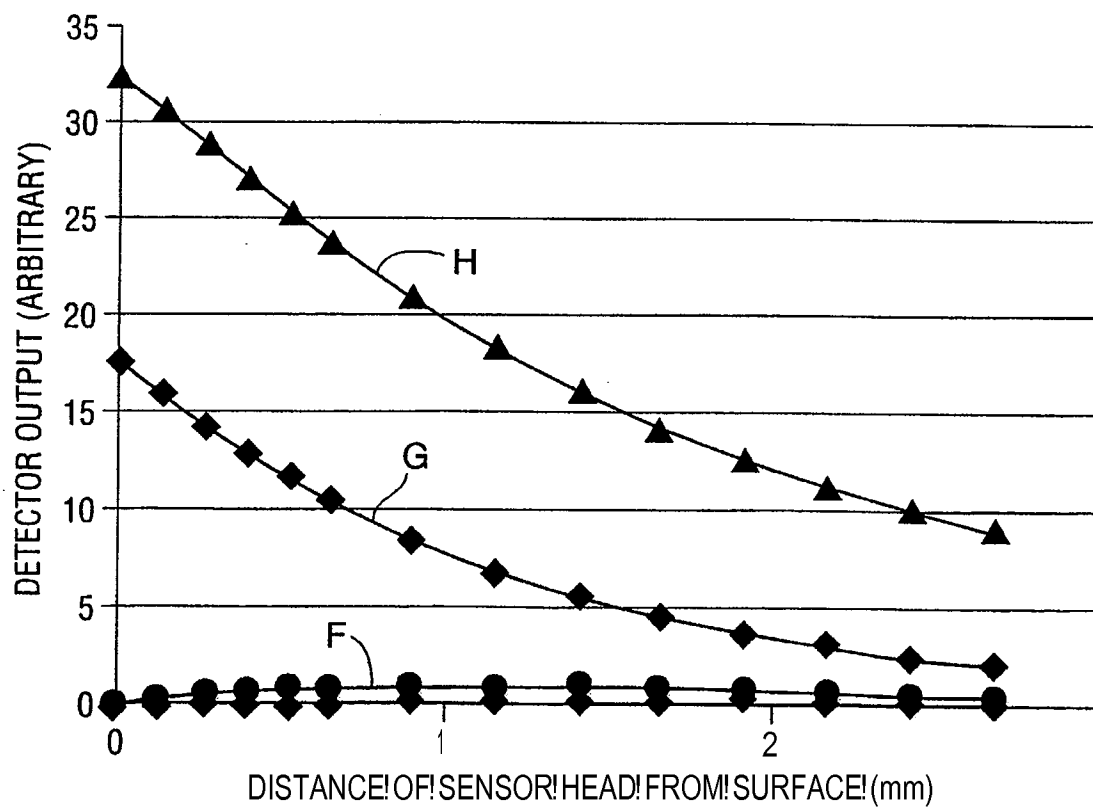
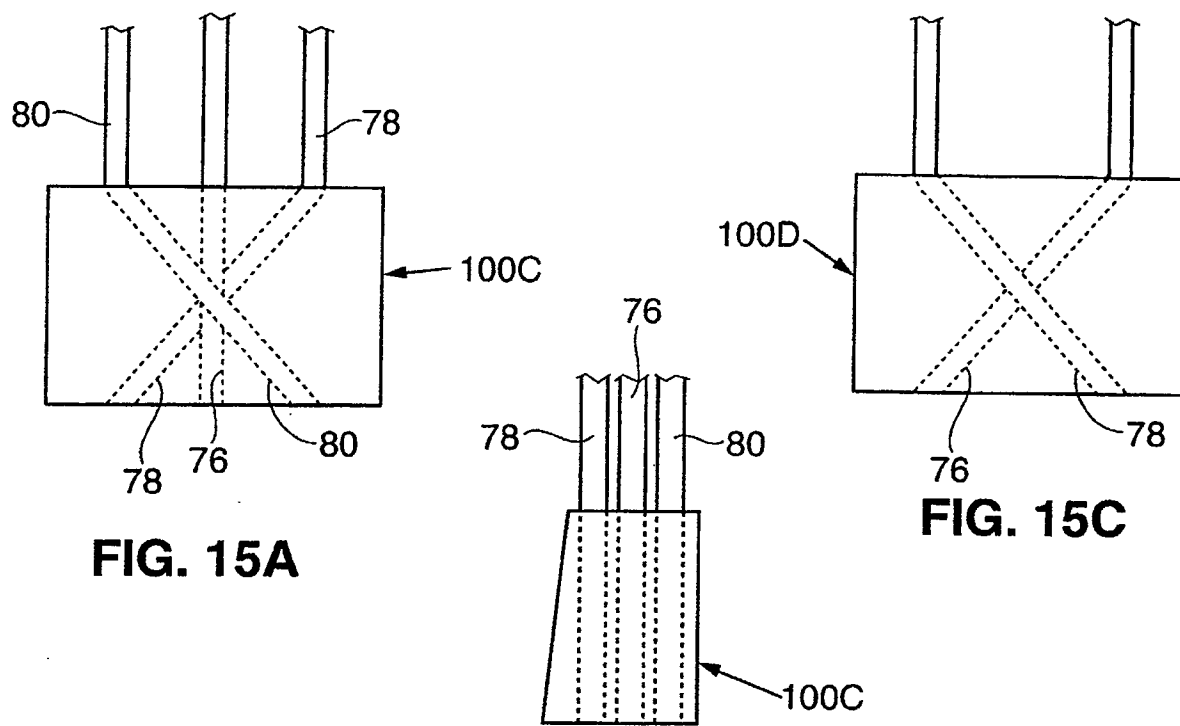


FIG. 15D

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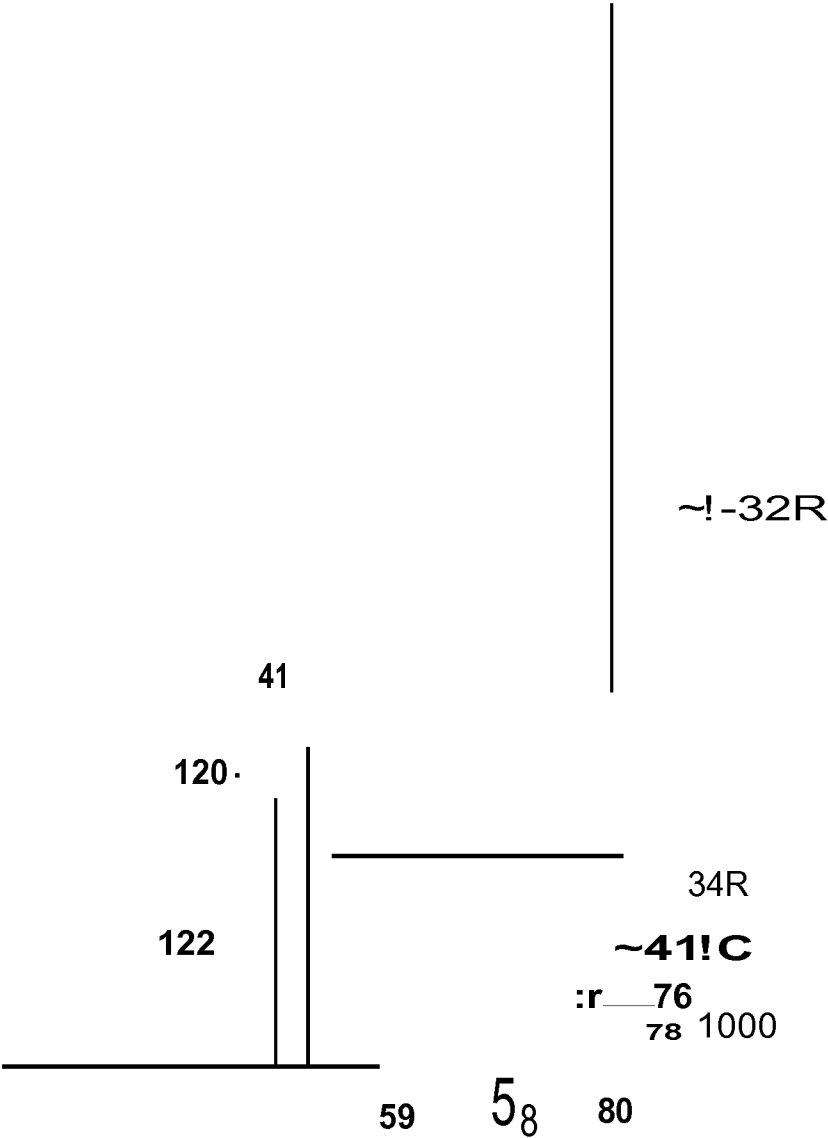
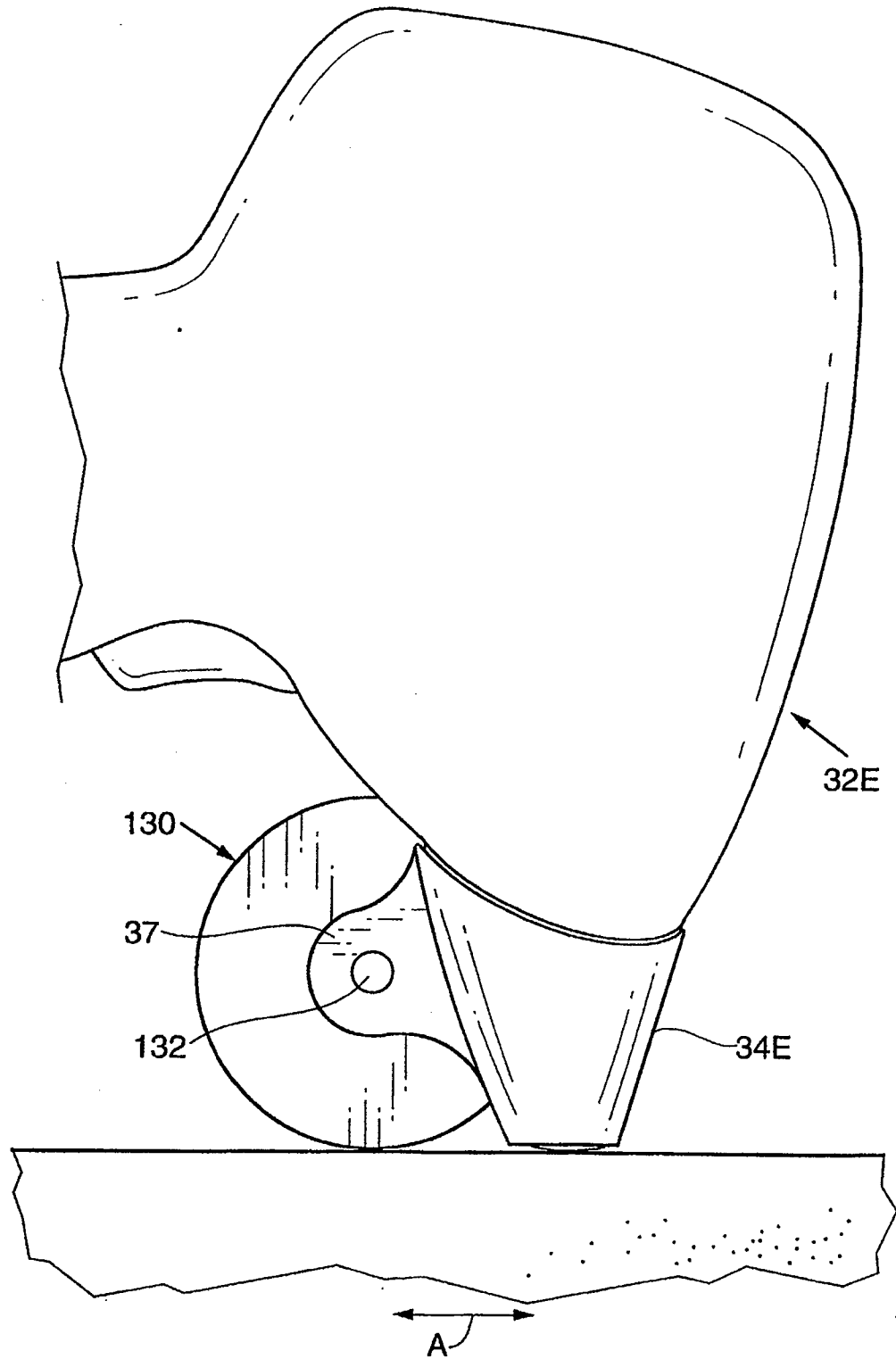


FIG. 16

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*0-18



■-18

FIG. 17

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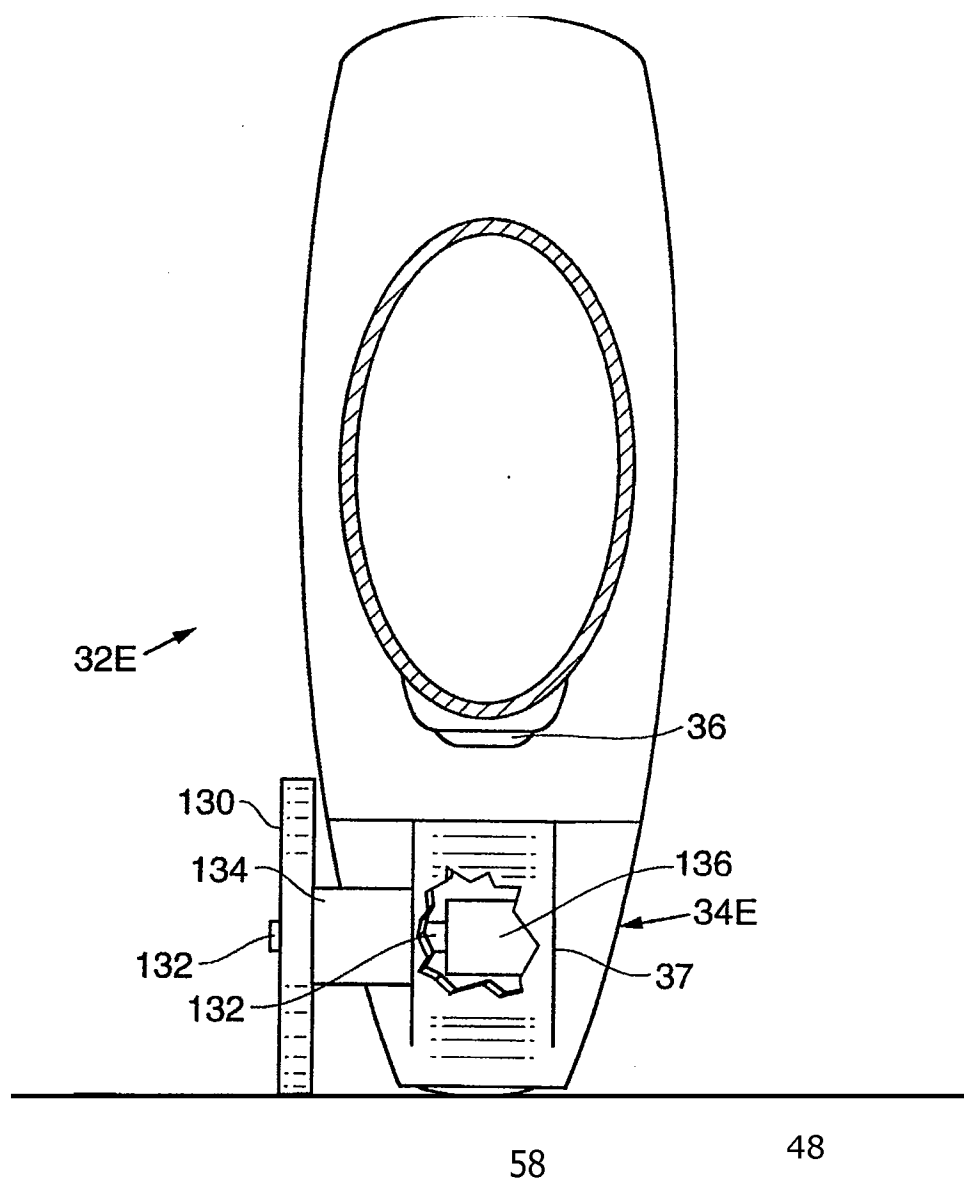


FIG. 18

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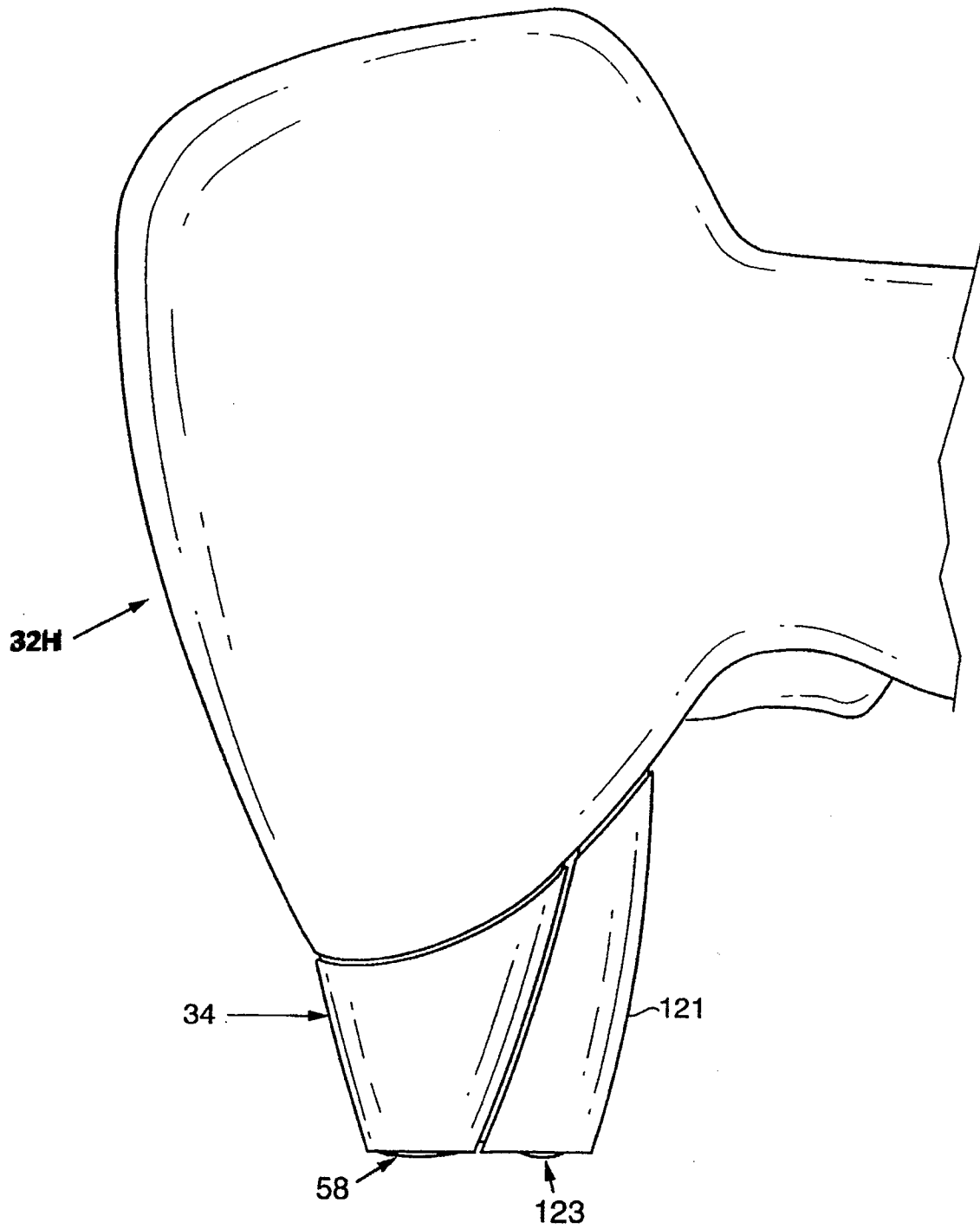


FIG. 19

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FIG. 20

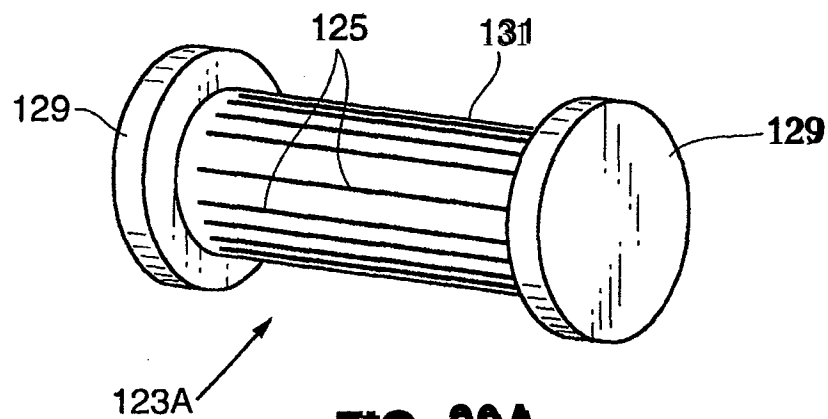
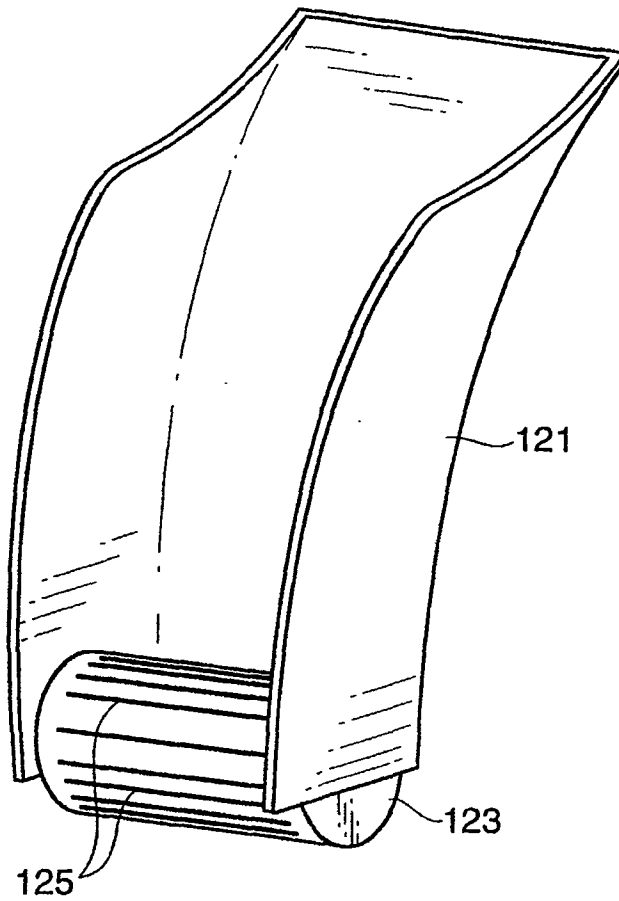


FIG. 20A

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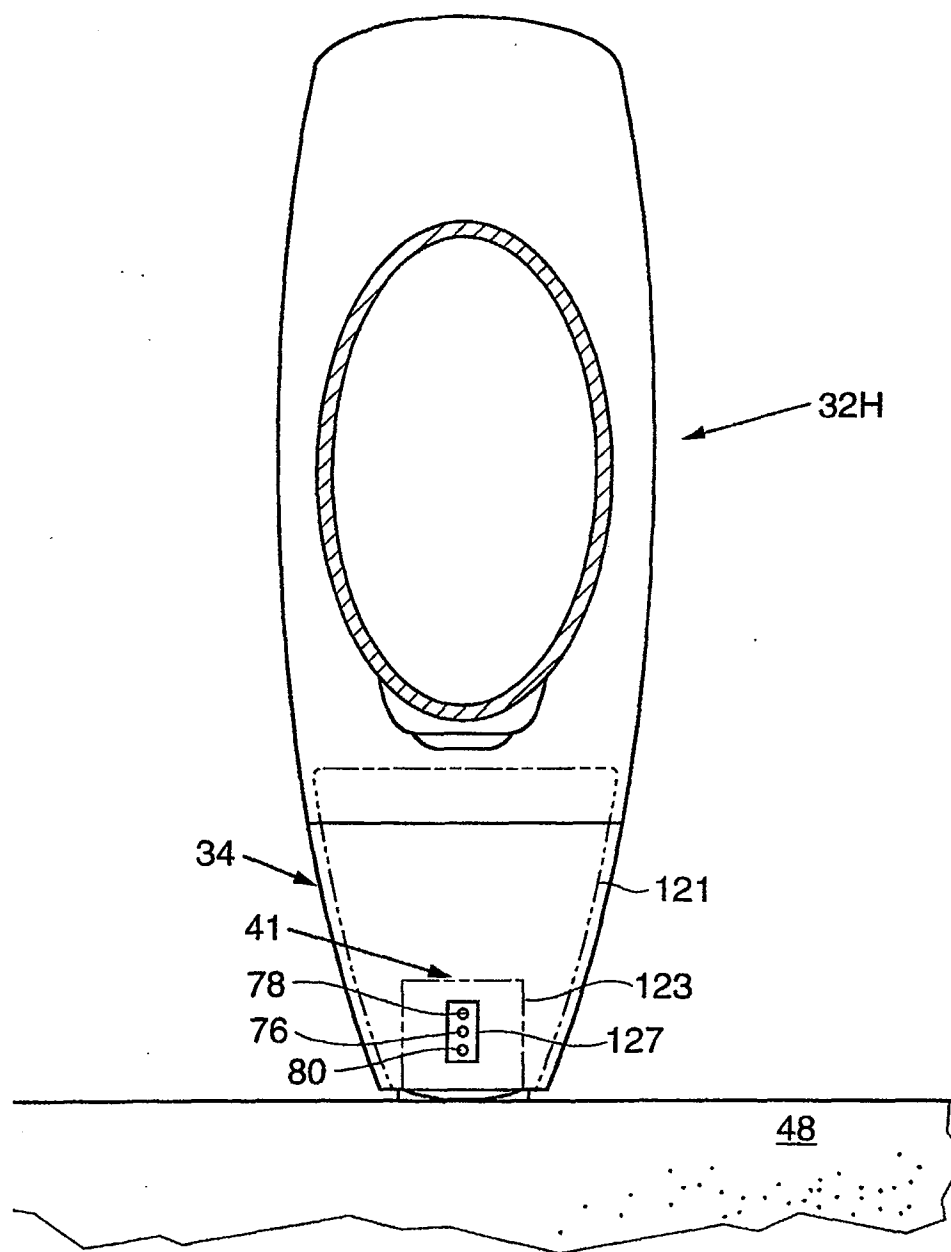


FIG. 21

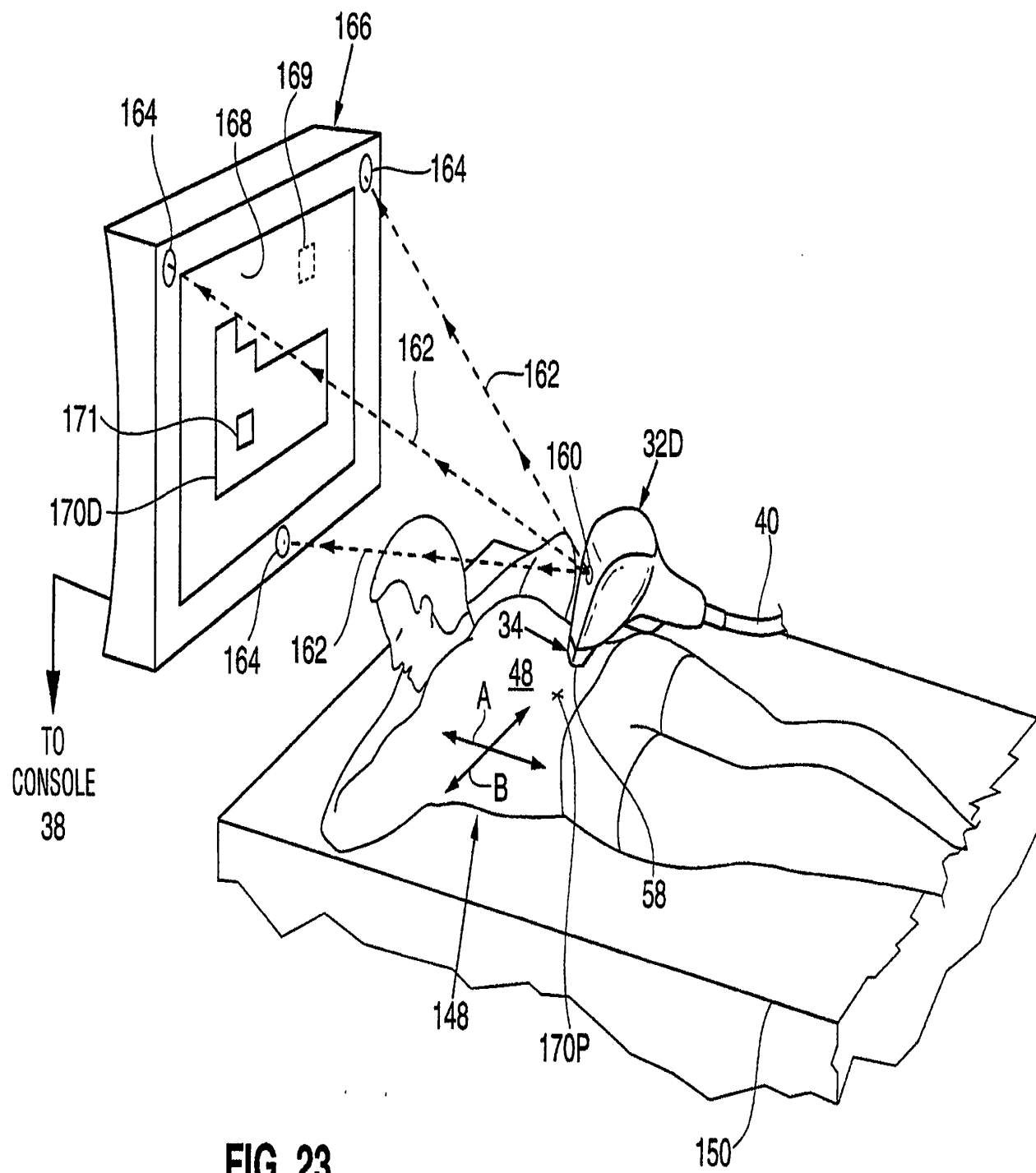


FIG. 23

INTERNATIONAL SEARCH REPORT

Interco Application No

PCT/US 00/26534

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61 18/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category ^o	Citation of document, with indication where appropriate, of the relevant passages	Relevant to claim No.
X	WO/ 98/ 51235! A! (GEN! HOSPITAL! CORP! ; PALOMAR MEDICAL! TECHNOLOGIES! I! (US)) 19! November! 1998! (1998-11-19) page! 5,! line! 3! -! line! 19 page! 8,! line! 23! -! line! 31 page! 18,! line! 7! -! line! 18 page! 20, line! 3! -! line! 7;! figure! 9	44, 49, 50
X	WO/ 99/ 11324! A! (ALLE! PETERSEN! OLAV! ; ASAH JARNE! (DK);! ASAH! MEDICO! A! S! (DK);! DOLLE) 11! March! 1999! (1999-03-11) column! 10, line! 32! -column! 12,! line! 21	44-48
X	US! 5! 501! 680! A! (NARAYANAN! KRISHNA ET! AL) 26! March! 1996! (1996-03-26) column! 2, line! 26! -column! 3, line! 20 column! 7,! line! 38! -! line! 54 -/-	44-48

X Further documents are listed in the continuation of box C.

X Patent family members are listed in annex.

^o Special categories of cited documents:

- document defining the general state of the art which is not considered to be of particular relevance
- E! earlier document but published on or after the international filing
- L! document which may throw doubts on priority claims or which is cited to establish the publication date of another citation or other special reason (as specified)
- document referring to an oral disclosure, use, exhibition or other means
- P! document published prior to the international filing date but later than the priority date claimed

later document published after the international filing date of parity date and not in conflict with the application but did not understand the principle of theory underlying the invention

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

document member of the same patent family

Date of the actual completion of the international search

19! December! 2000

Date of mailing of the international search report

28/12/2000

Name and mailing address of the ISA

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Fax! (+31-70) 340-3016

Authorized officer

Petter, E

INTERNATIONAL SEARCH REPORT

intern Application No

PCT/US 00/26534

C. (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with Indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,153,174 A (LACK MICHAEL) 2 July 1996 (1996-07-02) abstract	44-48
A	WO 97/22384 A (LASER IND LTD) 26 June 1997 (1997-06-26) page 4, line 6 - line 22; figures 9A, 9 page 11, line 16 - page 12, line 14 page 13, line 18 - page 14, line 13 page 10, line 23 - line 26	44-48
A	EI 0,898,983 A (NIDEK KK) 3 March 1999 (1999-03-03) column 3, line 55 - column 4, line 19 column 4, line 29 - line 46 column 9, line 39 - line 54	44-50

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US 5501680	A	26-03-1996	NONE	
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EP 0898983	A	03-03-1999	JP 11070121 A US 5971978!A	16-03-1999 26-10-1999